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Objective Analysis of Observational Data from the FGGE Observing Systems

W. Baker, D. Edelmann, M. Iredell,
D. Han, S. Jakkempudi

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Laboratory for Atmospheric Sciences

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Goddard Space Flight Center
Greenbelt, Maryland 20771

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FOREWORD

This technical memorandum has been prepared as a documentation for an objective analysis scheme developed at the Laboratory for Atmospheric Sciences. The analysis procedure was developed for numerical prediction studies with the FGGE data in an assimilation mode with the 4th order 4° x 5° GLAS GCM. Although the objective analysis scheme is continually evolving this documentation should be a useful reference.

Wayman E. Baker
1 March 1981

Acknowledgments

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LIST OF ACRONYMS

ADP	-	Automatic Data Processing
AIDS	-	Aircraft Integrated Data Systems
ASDAR	-	Aircraft to Satellite Data Relay
BLKSIZ	-	Blocksize
CPU	-	Central Processing Unit
CTW	-	Cloud-tracked winds
D/A	-	Direct Access
DD	-	Data Definition
DEVT	-	Device Type
DSNAME	-	Dataset Name
DSORG	-	Dataset Organization
DSRN	-	Dataset Reference Number
EXEC	-	Execute
FGGE	-	First GARP Global Experiment
FORTRAN	-	Formula Translation
FORTX	-	FORTRAN Extended Compiler
GARP	-	Global Atmospheric Research Program
GCM	-	General Circulation Model
GLAS	-	GSFC Laboratory for Atmospheric Sciences
GMT	-	Greenwich Mean Time
GSFC	-	Goddard Space Flight Center
HEX	-	Hexadecimal
ID	-	Identification
I/O	-	Input/Output
JCL	-	Job Control Language
JOBLIB	-	Job Library

LIST OF ACRONYMS (Continued)

LDR	-	Loader
McIDAS	-	Man computer Interactive Data Access System
NESS	-	National Environmental Satellite Service
NMC	-	National Meteorological Center
RECFM	-	Record Format
SCM	-	Successive Corrections Method
SSS	-	Scientific Supervisory System
SST	-	Sea Surface Temperature
TAU	-	Model Calendar
VTPR	-	Vertical Temperature Profile Radiometer

TABLE OF CONTENTS

1. INTRODUCTION

Preparation of the initial conditions for numerical forecasts has become increasingly complex with the augmentation to the conventional database (surface, rawinsonde, pilot balloon, and aircraft reports) of data from spaceborne observing systems (e.g. temperature retrievals from TIROS-N, cloud-motion wind vectors from geostationary satellites). Many of the non-conventional observing systems provide temperature, wind, or pressure only (see Table 1) with different error characteristics. This variety of data and errors must be addressed in an objective analysis scheme.

This documentation describes an objective analysis procedure developed at GLAS for the assimilation of the heterogeneous FGGE database with the 2nd and 4th order general circulation models. The objective analysis scheme is a modification of the Cressman (1959) scheme based on a method developed by Bergthórsson and Döös (1955). Additional information on the applications of the objective analysis procedure in numerical prediction studies with the FGGE data may be found in Baker (1981). The general circulation model (GCM) used most frequently in these studies, the GLAS 4° x 5° 4th order model, is described in detail in Kalnay-Rivas et al. (1977) and Kalnay-Rivas and Hoitsma (1979a). Documentation of the model is available in Kalnay-Rivas and Hoitsma (1979b).

Section 2 outlines the preparation of the FGGE data for analysis. The components of the objective analysis scheme are discussed in Section 3. Section 4 contains the organization of the objective analysis program and a description of the required data sets. Finally, the program logic and a detailed description of each subroutine is presented in Section 5.

Table 1. Data utilized from the FGGE observing systems.

Observing system	Data analyzed				Time data available (GMT)			
	p	T	u,v	RH	00	06	12	18
Rawinsondes		X	X	X	X	X	X	X
Pilot balloons			X		X	X	X	X
NAVAIDS		X	X	X	X	X	X	X
Dropwindsondes		X	X	X	X	X	X	X
TIROS-N		X			X	X	X	X
VTPR		X			X	X	X	X
Aircraft (conventional)		X	X		X	X	X	X
AIDS		X	X		X	X	X	X
ASDAR			X		X	X	X	X
NESS CTW			X		X		X	X
European CTW			X		X		X	
Wisconsin CTW (reprocessed Japanese winds)			X		X		X	
Wisconsin CTW (East/West)			X					X
Wisconsin CTW (Indian Ocean)			X		X		X	
Constant level balloons			X		X	X	X	X
Surface stations (land)	X	X			X	X	X	X
Ships	X	X	X		X	X	X	X
Drifting buoys	X				X	X	X	X

2. PREPARATION OF THE FGGE DATA FOR ANALYSIS

For this study the official FGGE II-b database, acquired from Sweden, is utilized. A preprocessor was developed to correct or delete "well-defined" errors and to order the data by latitude and longitude. The modifications to the database are described below.

All duplicate reports were eliminated. Fixed reporting stations were checked against a list of stations (provided by P. Kallberg of the European Centre for Medium Range Weather Forecasts) known to have had at least one occurrence of an incorrect geographical location. All ship locations were checked for possible erroneous land coordinates. It was not possible, however, to verify the correct position of ships over the ocean. Errors in excess of 100 mb in the sea level pressure reports (ship or land), caused by the ambiguity in the report code, are corrected in the objective analysis program by adding or subtracting 100 mb. We typically find no more than 5 to 10 such occurrences in a 6 h period.

All ASDAR temperature data were deleted because of an excessively warm bias found in the analysis of that data. Rawinsonde temperature and height data were corrected at 100 mb and above for the effects of incoming solar radiation on the thermistor with routines provided by G. Costello and J. Laver of the National Meteorological Center (NMC). Microwave retrievals from TIROS-N with precipitable water contamination were eliminated according to the criteria of Phillips (1980).

All cloud-motion wind vectors reported at 700 mb or below are re-assigned uniformly to 900 mb in the objective analysis program. We also re-assign all cloud-tracked winds reported above an estimated model tropopause to the tropopause level. Cloud-motion winds reported between 400 mb and the estimated model tropopause are re-assigned to the pressure level whose model temperature corresponds to the reported cloud-top temperature.

3. THE OBJECTIVE ANALYSIS SCHEME

In this section we describe the current version of the objective analysis and assimilation procedure. The objective analysis scheme is a successive corrections method (SCM) of the Cressman (1959) type which involves successive modifications to the first guess fields provided by the 4th order GLAS GCM (Kalnay-Rivas and Hoitsma, 1979). Eastward and northward velocity components u and v, geopotential height z, and relative humidity RH are analyzed on mandatory pressure levels. Surface pressure and temperature are reduced to sea level and analyzed there.

The analysis of geopotential height rather than temperature has the following advantages:

1) Significant level temperature data are utilized in computing rawinsonde mandatory level heights.

2) Calculation of the geostrophic wind is straightforward with a height analysis.

3) The mean error for large thicknesses computed from TIROS-N infrared retrievals is quite small.

The assimilation procedure involves the intermittent analysis of batches of data grouped in a ± 3 h window about each synoptic time. No attempt is made to balance the mass and motion fields.

3.1 Vertical interpolation between σ and P

The model first guess fields are updated every 6 h at the model σ levels while the data are analyzed at the mandatory pressure levels. This requires a double interpolation between σ and p. In regions of infrequent updating this results in excessive smoothing, as McPherson et al. (1979) point out. We have attempted to reduce the effects of the vertical interpolation by interpolating only the difference between the model first guess and the

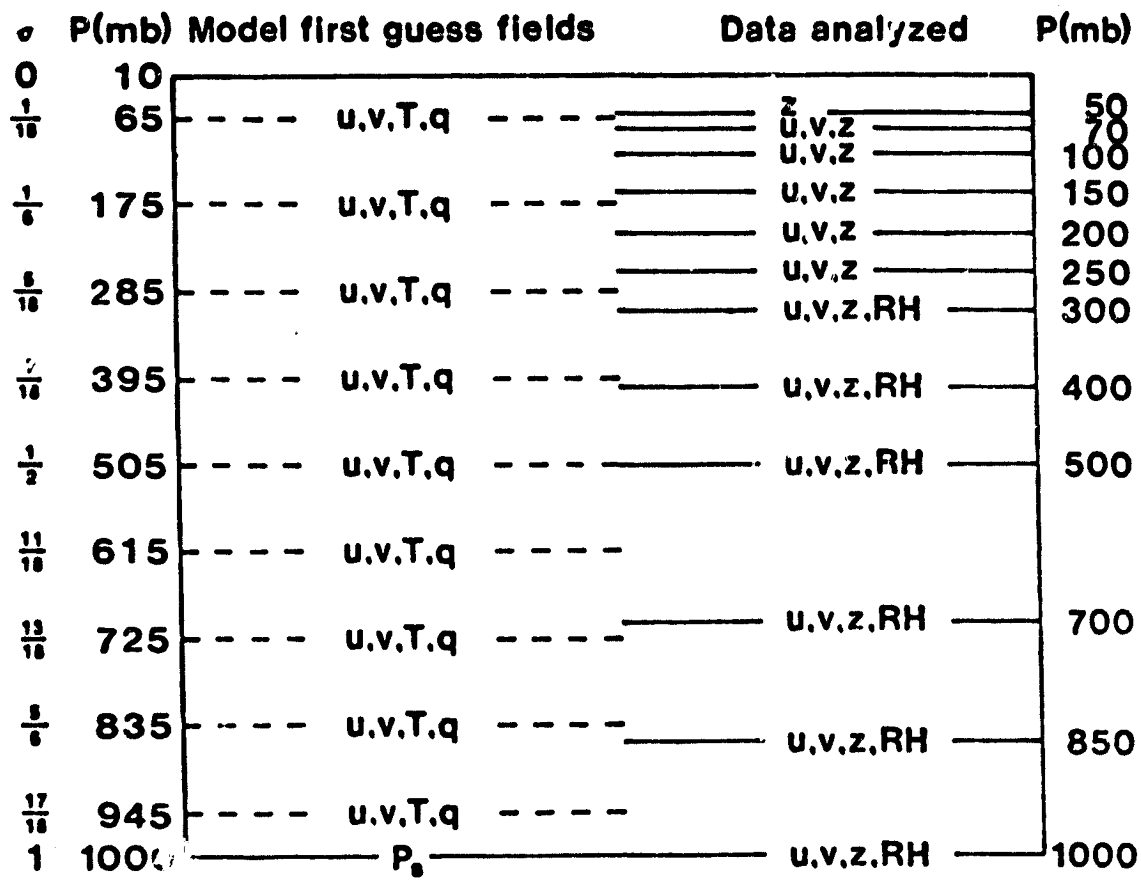

Fig.1 Nominal pressures of the 9-level 4th order GLAS GCM and the mandatory analysis levels.

analyzed fields (e.g. Δu, Δv, ΔRH) rather than the analyzed fields themselves Consequently, if a particular gridpoint is not affected by data, the difference between the first guess and the analyzed field is zero, and the first guess is returned to the model. Interpolating the difference between the model first guess and the analyzed field also helps to reduce interpolation errors where updating has occurred. However, even if the analysis and updating were performed in the model σ coordinate, the vertical interpolation problem would not be eliminated as McPherson et al. note.

The following vertical interpolation procedure is used. For the wind analysis, the first guess u and v wind components are interpolated (linear in log p) from the model σ levels to the mandatory p levels. After the analysis is completed, the differences between the model first guess and the analyzed fields are obtained at the σ levels by linear in log p interpolation. To avoid extrapolating above the top model σ level (nominally 65 mb) to obtain a 50 mb first guess wind field, a 50 mb wind analysis is not performed. Instead, we calculate

$$u_{65} = \hat{u}_{65} + \Delta u_{70} \qquad (1)$$

$$v_{65} = \hat{v}_{65} + \Delta v_{70} \qquad (2)$$

where $\hat{u}_{65}$ and $\hat{v}_{65}$ are the model first guess u and v wind components at the top σ level and Δu_{70} and Δv_{70} represent the difference in the model first guess and the analysis at 70 mb.

The vertical interpolation between σ and p for the relative humidity analysis is performed similarly except that relative humidity is first calculated from the model specific humidity q at the σ levels using the approximation

$$RH = q(p - 0.378e_s)/(0.622e_s) \tag{3}$$

where e_s is the saturation vapor pressure. We then evaluate e_s using the empirical formula of Tetens (1930) as modified by Murray (1967)

$$e_s = 6.11 \exp\,[a(T-273.16)/(T-b)] \tag{4}$$

where $a = 17.269$ and $b = 35.86$ if $T > 273.16$ and $a = 21.874$ and $b = 7.66$ if $T \le 273.16$. Next, RH is interpolated (linear in log p) to the p levels and analyzed at 300 mb and below (see Fig. 1). RH is then interpolated to the model σ levels in the same manner as was done for u and v, followed by the calculation of q using Eq. (3). No change is made in the first guess specific humidity field above 300 mb.

We analyze the geopotential height z of the mandatory p levels, whereas a first guess temperature field is provided at the model σ levels. This requires a somewhat more complicated procedure than was needed for the wind and moisture analysis. To prepare the model first guess z field for updating with the observations at the mandatory p levels, a linear in log p interpolation is performed to obtain the model σ-level temperatures[1] at the mid-mandatory p levels. The hydrostatic equation

$$p^{-1}\partial p/\partial z = -g(RT)^{-1} \tag{5}$$

is then integrated from sea level to 50 mb to obtain the model first guess geopotential height at each mandatory pressure level. In Eq. (5), g is the gravitational constant and R the gas constant for dry air.

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[1] Virtual temperature is actually interpolated.

First, to compute the first guess geopotential height of the 1000 mb surface z_{1000}, we integrate Eq. (5) from sea level to 1000 mb to obtain

$$z_{1000} = T_{s\ell} /[g/R(\ell n(p_{s\ell}/1000)) + 0.5\beta] \tag{6}$$

where β = 6.5 °C/km, the standard atmospheric lapse rate, $T_{s\ell}$ the sea level temperature, and $P_{s\ell}$ the sea level pressure. In Eq. (6), $T_{s\ell}$ is calculated as

$$T_{s\ell} = T_s + \beta z_s \tag{7}$$

with z_s and T_s the elevation and temperature, respectively, of the model lower boundary (σ = 1). The sea level pressure $p_{s\ell}$ is determined from

$$p_{s\ell} = p_s \exp[g z_s (RT_m)^{-1}] \tag{8}$$

where p_s is the model surface pressure and T_m the layer mean temperature between sea level and the surface expressed as

$$T_m = T_s + 0.5\beta z_s \tag{9}$$

To calculate the first guess geopotential height at the p levels above 1000 mb, we integrate Eq. (5) from 1000 mb to 50 mb using

$$z_{k+1} = z_k + c_p g^{-1} \; T_\ell \; (p_k^\kappa - p_{k+1}^\kappa)/p_\ell^\kappa \tag{10}$$

where k indexes the mandatory levels and ℓ the mid-mandatory levels, c_p is the specific heat at constant pressure, and $\kappa = R/c_p$. The mid-mandatory level pressure p_ℓ raised to the power κ in the denominator of the bracketed quantity in Eq. (10) is computed as,

$$p_\ell^\kappa = (\kappa+1)^{-1} \left(p_k^{\kappa+1} - p_{k+1}^{\kappa+1}\right)/(p_k - p_{k+1}) \tag{11}$$

which assumes a constant potential temperature in each layer after Phillips (1974). p_ℓ^κ is defined similarly in the forecast model (Kalnay-Rivas et al., 1977). In the interpolation of the σ-level temperature profile to obtain T_ℓ in Eq. (10), described previously, the pressure p_ℓ corresponding to each T_ℓ is computed using Eq. (11).

After the geopotential height analysis has been completed, mid-mandatory level temperatures are calculated. Using Eq. (10) we solve for T_ℓ such that

$$T_\ell = g c_p^{-1} (z_{k+1} - z_k)\, p_\ell^\kappa \left(p_k^\kappa - p_{k+1}^\kappa\right)^{-1} \tag{12}$$

The difference between the analyzed T_ℓ and the first guess T_ℓ is then interpolated linear in log p to the σ levels and added to the original model temperature profile. The updated σ-level temperature T_σ may be expressed as

$$T_\sigma = \hat{T}_\sigma + \Delta T_\sigma \tag{13}$$

where $\hat{T}_\sigma$ is the first guess temperature and ΔT_σ the interpolated difference between the analyzed T and the first guess T. We assume that the difference in dry bulb temperature ΔT_σ is very nearly equal to the difference in virtual temperature.

3.2 Data selection and horizontal consistency

After the observational data have been ingested, a comparison is made between the data and the model first guess fields interpolated to constant pressure surfaces (see Fig. 1) as previously described. Data which differ from the model first guess by a specified amount are flagged as suspect. The maximum allowable differences between the observations and the model first guess are shown in Table 2. The choice of these "acceptance criteria" is arbitrary. We were guided in our selection of these criteria by the desire to use all available "good" data at the risk of including a few "bad" reports.

After all the data have been checked against the model first guess, those data flagged as suspect are rechecked by comparing the average difference between the nearby reports (observations within a 5° radius) and the model first guess with the difference between the model first guess and the observation in question. An observation is rejected whose difference from the model first guess differs from the average of the nearby differences by more than the limits given in Table 2.

3.3 Interpolation of observational data to the horizontal grid

The method of interpolating the observations to the 4° x 5° analysis grid is based on the Cressman (1959) scheme, but modified to treat variable data density and quality and the first guess accuracy of the prediction model. The interpolation procedure is described below.

Let the total correction to the background field C_k be expressed as

$$C_k = \sum_{i=1}^{N} w_i \Delta F_i / \left(\sum_{j=1}^{M} w_j + \sum_{i=1}^{N} w_i \right) \qquad (14)$$

Table 2. Maximum differences (observations - model first guess) permitted in the data screening process.

Analysis level (mb)	z (m)	u, v ($m\ s^{-1}$)	RH (%)	p (mb)	T (K)
50	400	-	-	-	-
70	375	25	-	-	-
100	350	25	-	-	-
150	325	25	-	-	-
200	300	30	-	-	-
250	275	30	-	-	-
300	250	30	50	-	-
400	200	25	50	-	-
500	150	20	50	-	-
700	100	20	50	-	-
850	50	20	50	-	-
1000	-	15	50	-	-
Sea level	-	-	-	15	20

where k indexes the number of scans (k =1-3 in the present scheme), i the N observations available in the kth radius about a model gridpoint, j the surrounding M gridpoints about the gridpoint that is to be updated, and ΔF_i denotes the deviation of each observation from the first guess field. The deviations are calculated using a bilinear interpolation of the four model gridpoints surrounding each observation. The background field is then subtracted from the observed data.

In Eq. (14), w_i and w_j represent the weight given to the ith observation and jth gridpoint prediction, respectively. We define

$$w_i = q_i(R_k^2 - r_i^2)/(R_k^2 + r_i^2) \tag{15}$$

and

$$w_j = q_j(R_k^2 - r_j^2)/(R_k^2 + r_j^2) \tag{16}$$

where R_k is the size of the kth radius of influence about each model gridgoint, r_i the distance from the ith observation to the model gridpoint to be updated, and r_j the distance from the jth surrounding gridpoint to the gridpoint being analyzed. R_k, determined as a function of data density, is defined as

$$R_k = c_k d \tag{17}$$

where d is the average distance between observations within a given radius about each gridpoint. In Eq. (17), d may be expressed as

$$d = (\pi/N)^{1/2}\, r_d \tag{18}$$

where N is the number of observations within a radius r_d (800 km in this study). In Eq. (17), the coefficient c_k is chosen to be 1.6, 1.4, or 1.2 for scans 1,2 or 3, respectively, after Stephens and Stitt (1970).

In Eqs. (15) and (16), q_i and q_j are pre-assigned observational and first quess weights, respectively. Values for q_i represent the ratio of the mean squared error of the rawinsonde data to the mean squared error of all other data. Rawinsonde data are given full weight in this analysis scheme with respect to observational accuracy. For non-rawinsonde data q_i ranges from 0.0 to 1.0. In cases where the mean squared rawinsonde error is greater than that for other data, $q_i = 1.0$ for that data.

The rms differences that are used to compute the observational weights are computed using the NMC final analysis. A ± 3 h window is used about each 6 h analysis with the same data checking criteria given in Table 2. The matchups between the NMC analysis and the observations are accomplished with a horizontal bilinear interpolation of the NMC analysis to the location of each observation at each mandatory level. For off-level wind reports, the NMC analysis is interpolated vertically linear in log p to the reported pressure levels. Differences between the analysis and the observations are then obtained and assigned to the nearest mandatory level for inclusion in the rms calculation. The rms differences for off-level aircraft temperature data are obtained similarly except that geopotential height is computed at the nearest mandatory level for the aircraft report.

The quality of the first guess field q_j represents the ratio of the mean squared error of the rawinsonde data to the mean squared error of the 6 h prediction augmented by the update history of each gridpoint at each level. The mean squared prediction error is not permitted to grow beyond 72 h in regions of infrequent updating. No attempt is made to account for varying data quality in the update history (McPherson et al., 1979). In compiling the

error statistics for the model prediction, each 6 h analysis during a 32 d assimilation experiment utilizing the FGGE Level II-b data is used to verify the 6 h first guess for 127 cases.

For the horizontal interpolation of the wind data to the analysis grid, the distance weighting in Eq. (15) is modified to allow upwind or downwind observations to have greater weight than crosswind observations as was done by Endlich and Mancuso (1968) for analyses of jet maxima. In the present scheme we modify Eq. (15) such that

$$w_i = q_i [R_K^2 \cos\phi + (R_K^2 - r_i^2)\sin\phi]/(R_K^2 + r_i^2) \tag{19}$$

which is similar to the weighting function used by Bergman and Carlson (1975) for analyses of tropical cyclones.

3.4 Updating the Model Fields

3.4.1 Analysis of the mass field

After first guess fields of $T_{S\ell}$ and $p_{S\ell}$ have been obtained using Eqs. (7) and (8), respectively, the background fields are modified by the observational data using Eq. (14). All available land and ship reports are analyzed. In the present scheme, wind observations do not affect the sea level pressure analysis. An 8th order Shapiro (1970) filter is applied once after the third scan in the analysis of $p_{S\ell}$ and $T_{S\ell}$.

The model surface pressure is updated by solving for p_S in Eq. (8). The vertical coordinate of the model is then adjusted using

$$\sigma = (p - p_T)/(p_S - p_T) \tag{20}$$

where $p_T = 10$ mb, the pressure at the top of the model.

3.4.2 Updating the thermal field

In order to update the model σ-level temperatures, a background height field is obtained at the mandatory pressure levels as previously described. Height profiles are constructed for single-level aircraft temperature data using Eq. (10). A first guess height profile is assumed below the level of the aircraft report, with the aircraft temperature data modifying the height profile at all mandatory levels above the aircraft level.

Hydrostatic consistency is maintained in the vertical by checking the static stability of each layer against the limits given in Table 3, where D represents the actual height minus the reference height and S the layer mean stability. The superscript 6 refers to the 6 h model first guess. The information for the first 10 levels contained in Table 3 was provided by J. McDonell of the NMC Automation Division. Two additional levels were added at 70 mb and 50 mb to accommodate the analysis at 12 levels.

First, z_{1000} is calculated using Eq. (6). The SCM is then applied to the 300 mb first guess height field. We followed the procedure established in 1971 at NMC (see Tech. Procedures Bulletin No. 63) of selecting the 1000 mb and 300 mb surfaces as key levels because of the abundance of sea level and aircraft data affecting those levels, respectively. The information at 300 mb is reflected in the levels above and below 300 mb through the calculation of the first guess (defined in Table 3) at those levels. Similarly, the first guess for levels above 1000 mb is influenced by the 1000 mb analysis.

As an example, consider the calculation of D_{500} (z_{500} - reference height), defined in Table 3 as

$$D_{500} = .383\ D_{1000} + .617\ D_{300} + S^{6}_{500} \qquad (21)$$

Table 3. Geopotential height first guess defined by level in the order of computation with the corresponding stability (S) limits. The information for the first 10 levels was provided by J. McDonell.

Level (mb)	Definition of the first guess height field	S (m)
1000	Computed from Psℓ first quess	——
300	Computed from temperature first quess	——
500	$D_{500} = 0.383\ D_{1000} + 0.617\ D_{300} + S^{6}_{500}$	-204 to 125
700	$D_{700} = 0.461\ D_{1000} + 0.539\ D_{500} + S^{6}_{700}$	- 70 to 43
850	$D_{850} = 0.532\ D_{1000} + 0.468\ D_{700} + S^{6}_{850}$	- 40 to 25
400	$D_{400} = 0.545\ D_{500} + 0.455\ D_{300} + S^{6}_{400}$	- 71 to 26
200	$D_{200} = 1.696\ D_{300} - 0.696\ D_{500} - 1.696\ S^{6}_{300}$	-128 to 397
250	$D_{250} = 0.536\ D_{300} + 0.464\ D_{200} + S^{6}_{250}$	- 50 to 30
100	$D_{100} = 2.463\ D_{200} - 1.463\ D_{300} - 2.463\ S^{6}_{200}$	-582 to 289
150	$D_{150} = 0.561\ D_{200} + 0.439\ D_{100} + S^{6}_{150}$	- 49 to 108
50	$D_{50} = 1.818\ D_{100} - 0.818\ D_{200} - 1.818\ S^{6}_{100}$	-100 to 444
70	$D_{70} = 0.461\ D_{100} + 0.539\ D_{50} + S^{6}_{70}$	- 80 to 106

First, rewrite Eq. (5) as

$$\partial z/\partial \pi = -c_p\, g^{-1}\, \theta \tag{22}$$

where π is the Exner function and θ the potential temperature. Eq. (22) may then be integrated from 1000 mb to 500 mb to obtain

$$z_{500} - z_{1000} = c_p g^{-1}\, \bar{\theta}_{1000}^{500}\, (\pi_{1000} - \pi_{500}) \tag{23}$$

Integrating Eq. (22) from 500 mb to 300 mb yields

$$z_{300} - z_{500} = c_p g^{-1}\, \bar{\theta}_{500}^{300}\, (\pi_{500} - \pi_{300}) \tag{24}$$

In Eqs. (23) and (24), $\bar{\theta}_{1000}^{500}$ and $\bar{\theta}_{500}^{300}$ represent the mean potential temperature of the indicated layers. We may then use

$$D_{500} = z_{500} - 5572 \text{ m} \tag{25}$$

and Eqs. (23) and (24) to obtain Eq. (21). In Eq. (21), S_{500}^{6} is computed from the model first guess with the following expression

$$S_{500}^{6} = D_{500}^{6} - .383\, D_{1000}^{6} - .617\, D_{500}^{6} \tag{26}$$

After calculating D_{500} in Eq. (21), the SCM is applied to z_{500} and a new stability factor S_{500} is computed as

$$S_{500} = D_{500} - .383\, D_{1000} - .617\, D_{300} \tag{27}$$

S_{500} is reset to -204 m or to 125 m for those temperature profiles which are either too stable or too unstable, respectively, in the 1000 mb to 300 mb layer. D_{500} is then recalculated after substituting S_{500} from Eq. (27) for S_{500}^{6} in Eq. (21). The calculation of D_{500} and S_{500} is repeated for the second and third scans with the stability checked and reset, if necessary. As with the sea level pressure and temperature, an 8th order Shapiro filter is applied once to the height

field after the third scan. The other levels are analyzed in the order given in Table 3. The model σ-level temperatures are then updated in the manner previously described.

3.4.3 Analysis of the wind and moisture fields

An analysis of the wind field is performed at 11 mandatory levels (1000 mb to 70 mb) with corrections made to the background field using Eq. (14). The 50 mb analysis is excluded to avoid extrapolation, as discussed previously. Cloud-motion wind vectors are re-assigned prior to modifying the first guess field as described in Section 2. Single-level wind data (i.e. aircraft, cloud-motion winds, etc.) are allowed to affect the analysis at the two mandatory levels adjacent to the wind report. We use wind data from ships only in the 1000 mb analysis.

Before applying the SCM, a local geostrophic correction is applied to the first guess wind field using a technique similar to that proposed by Kistler and McPherson (1975). However, the geostrophic correction is computed from the change (analysis-first quess difference) to the mass field (surface pressure) only. This approach has been tested successfully by Stone et al. (1973) and is in use operationally at the Australian Numerical Meteorological Research Center (K. Puri, personal communication). First guess and analyzed values of Z_{1000} are obtained using Eq. (6) from which corresponding fields of the geostrophic wind are computed. The first guess wind field is then adjusted using

$$\mathbf{v} = \hat{\mathbf{v}} + [\ gf^{-1}\ (\nabla Z^{6}_{1000} - \nabla Z_{1000})]\ \times\ 1k \tag{28}$$

which is Eq. (1) in Kistler and McPherson. In Eq. (28), $\hat{\mathbf{v}}$ is the first guess vector wind field and f the coriolis parameter. The adjustment to the first

guess wind field is scaled vertically and latitudinally using Eqs. (3.19) and (3.20) in Bergman (1979). An 8th order Shapiro filter is applied at each of the 11 analysis levels after the third scan of the SCM. The model σ-level wind field is updated as previously described.

Relative humidity is analyzed using Eq. (14) at six mandatory levels (1000 mb to 300 mb). There is no interaction between the moisture field and the other fields during the analysis. As with the other fields, an 8th order Shapiro filter is applied once after the final scan in the RH analysis. Updated σ-level values of specific humidity are obtained using the procedure discussed previously.

4. PROGRAM ORGANIZATION AND DATA SET DESCRIPTION

4.1 Objective Analysis Modules

The FORTRAN program which performs the objective analysis consists of subroutines contained in three source modules:

- GWS.MI.FORTH.ANALYSIS.FORT — Objective analysis
- I6I2HC9A — Level II-a unpacking
- I6I2U2B — Level II-b unpacking

The object code equivalent of the objective analysis is contained in one module:

- I726FA01

4.2 Source modules for the 4th Order Model

Execution of the objective analysis requires on-line interaction with the 4th order model. The FORTRAN programs that constitute the model are contained in five source modules.

- I761DHF2 Old master: Main and hydrodynamics
- I761DH13 Old master: Physics
- I761RADN Old master: Long-wave radiation
- I761DHT1 Old master: Short-wave radiation
- GWS.MI.FORT.UTILITY.PDS (RFFTI) Old Master: Fast-Fourier transform

The current version of the model is obtained via updates to the old masters and is contained in object form in two modules:

- I7624TH4 Object code: Main, hydrodynamics, physics, and long-and short-wave radiation
- I762RFFT Object code: Fast-Fourier transform

In addition, a library of routines is contained in:

- I527JLIB

4.3 Source Modules for the Objective Analysis

The module

- GWS.MI.FORTH.ANALYSIS.FORT

contains the following 85 subroutines and 4 entries (indented):

- ADPINS
- ALTER2
- ATESTA
- ATESTH
- ATESTP
- ATESTQ
- ATESTT
- ATESTU
- ATESTW
- ATEST3
- CDGRID
- CHKADP
- CONSTT
- CUTADP
- DFDX4
    - DFDY4
- DIFFRS
- DUMMYZ
    - INSMIT
    - TTHC9A
- FILLIN
- FIND
- FINDHM
- FINDLV
- FVARIO
- GCDIR
- GCDIST
- GEOSAD
- GEOSM
- GEOTOT
- GETAHT
- GETEMP
- GETFGW
- GETWND
- GRIDCD
- GTOPOG
- GTTOT
- HITEMP
- HUMID
- INCMN
- INSEAL
- INSURF
- INUPAR
- KINDEX
    - DINDEX
- LEQ1
- LOC
- LOCATE
- LQEU
- LQUS
- MAPP
- NEWTPE
- NEXT
- NMCHIT
- NMCSCM
- PAIRZ
- PARA
- PCAL
- POTEMP
- PRESIG
- PSIGMA
- PSURFE
- PTOSIG
- PUTWS
- QE
- READIN
- RELDEW
- RELHUM
- RINDX1
- RINDX2
- SATSND
- SATURN
- SBLIZE
- SCALE
- SHAPFL
- SHUM
- SIGTOP
- SMOCC
- SMOOTH
- SMPSL2
- SM2D
- SPEHUM
- SSCAN
- TAP24
- TERP
- TSFACT
- WINDPR
- WIND2
- $SMOO9

The module

- I612HC9A

contains the following 9 subroutines:

TTHC9A	TTINT	FIX
GETCAT	UPKID	UPKST3
LOAD	UPKSTA	UPKST5

The module

- I612U2B

contains the following 9 subroutines:

FORM2B	UPK2BW	IFROMA
UPK2BB	REED37	RFROMA
UPK2BU	NEWHDR	TESDAT

4.4 Job Control Language for Execution

```
/ID
/DD     5    DSNAME=I612HC9A
/DD     6    DUMMY(133)
/EXEC        FORTX
/DD     5    DSNAME=I612U2B
/DD     6    DUMMY(133)
/EXEC        FORTX
/JOBLIB      DSNAME=1527JLIB
/SIZE=4500K
/DD     8    DSNAME=I7624TH4
/DD     9    DSNAME=I762RFFT
/DD     19   DSNAME=I762FA01
/EXEC        LDR,'HEX'
 INCLUDE 8
 INCLUDE 9
 INCLUDE 19
/DD     6    DUMMY(2600)
/DD     8    DEVT=2409,RECFM=U,LRECL=7680
/DD     11   DEVT=CORE,LRECL=84,SPACE=10
/DD     12   DEVT=T6250,RECFM=U,LRECL=20000
/DD     17   DSNAME=1527SMFZ
/DD     40   DSNAME=1527ALBE
/DD     46   DSNAME=CIAPF79T
/DD     51   DSNAME=GDBYSST1
/DD     55   DSNAME=I751DATO
/DD     56   DSNAME=CIBKDAT1
/DD     21   DSNAME=I763MF17
/DD     23   DSNAME=I763AAGG,RECFM=F,LRECL=372,DSORG=DA
/DD     24   DUMMY(2600)
/DD     25   DEVT=2409
/DD     26   DSNAME=I763RMSA
/DD     61   DSNAME=I763FQW3
/DD     81   DSNAME=I763SEAX,RECFM=F,BLKSIZ=2960,LRECL=2960
/DD     82   DSNAME=I763SEAZ,RECFM=F,BLKSIZ=2960,LRECL=2960
/DD     83   DSNAME=I763AAGB,RECFM=F,BLKSIZ=2960,LRECL=2960
/DD     84   DSNAME=I763SEA1,RECFM=F,BLKSIZ=2960,LRECL=2960
/DD     85   DSNAME=I763SEAY,RECFM=F,BLKSIZ=2960,LRECL=2960
/DD     86   DSNAME=I763AAGD,RECFM=F,BLKSIZ=2960,LRECL=2960
/DD     87   DSNAME=I763PFT2
/EXEC        *
 &INPUTZ
 &END
 &ALPUTZ
 &END
/*
```

4.5 Input Data Parameters

4.5.1 Namelist INPUTZ

Namelist INPUTZ defines parameters which vary according to the particular model experiment. They will, therefore, not be described in this report.

4.5.2 Namelist ALPUTZ

FORTRAN parameter	Description	Default	Type
INSADP	Time interval for data analysis	6	I4
NKOUNT	Log 24 tape flag (0 for no output)	0	I4
ASTART	Initial conditions flag (1 for σ-level tape)	0.	R4
MAXDEX	Number of data types used in analysis	7	I4
QX	See Section 4.5.2.1	100*.FALSE.	L1
QELLIP	Elliptical weighting for wind data	.FALSE.	L4
NSAT	Number of satellite sounding data sets	0	I4
LUSAT	Logical units for sounding data sets	1:10*0, 2:10*1	I4
QGEOS	Geostrophic wind correction	.False	L4
WMLAT	Maximum latitude for wind analysis	90.	R4
NTOPOG	DSRN for topography used in PTOSIG	0	I4

4.5.2.1 <u>Data Type in the QX array</u>

Location in QX array	Description
1	Surface, rawinsonde, and pilot balloon data
2	Aircraft
3	ASDAR
4-7	NESS EAST, NESS West, European, and Japanese cloud-tracked winds
8	Drifting buoys
9-11	Wisconsin East, West, and Indian Ocean cloud-tracked winds
12	Constant level balloons
13	NAVAIDS
14	Dropwindsondes
15-32	TIROS-N soundings
33-50	Special effort soundings
51-56	VTPR soundings

4.6 Data Set Description

DSRN	Status	Organization	Description
8	Output	Seq.	Model history tape
11	Input/Output	Seq.	Temporary namelist core space
12	Input	Seq.	σ-level initial conditions
17	Input	Seq.	Surface geopotential height
40	Input	Seq.	Surface albedo
46	Input	Seq.	Topography
51	Input	Seq.	SST/snow cover data
55–56	Input	Seq.	Radiation data
21	Input	Seq.	Mandatory-level initial conditions
23	Input/Output	D/A	Temporary storage for mandatory-level data
24	Output	Seq.	Analyzed fields at mandatory levels
25	Input	Seq.	Level II-a data
26	Output	Seq.	Values of rms fit
61	Input	Seq.	Quality weights
81	Input	Seq.	Buoy data
82	Input	Seq.	Wisconsin East and West CTW data
83	Input	Seq.	Wisconsin Indian Ocean CTW data
84	Input	Seq.	Constant level balloon data
85	Input	Seq.	NAVAIDS data
86	Input	Seq.	Dropwindsonde data
87	Input	Seq.	TIROS-N data

4.6.1 <u>DSRN 8. Model History Tape</u>

The model history tape (165 format) is described in detail in Edelmann (1980).

4.6.2 <u>DSRN 12: Sigma-Level Initial Conditions</u>

The initial conditions for the model experiments are described in Edelmann (1980).

4.6.3 <u>DSRN 17: Surface Geopotential Height</u>

A description of the surface geopotential height is given in Baker <u>et al.</u> (1980).

4.6.4 <u>DSRN 46: Topography</u>

A description of the topography dataset is given in Baker <u>et.al</u> (1980).

4.6.5 <u>DSRN 51: Sea Surface Temperature and Snow Cover</u>

Item number	Data element	Type	Number of words
1	Simulated time (TAU)	R*4	1
2	Comment array	R*4	300
3	Snow cover (=1)	R*4	3312
4	Sea surface temperature (K)	R*4	3312

4.6.6 DSRN 21: Mandatory Level Initial Conditions

Item number	Data element	Units	Dimension	Type	Number of words
	Record No. 1				
1	TAU	h		R*4	1
2	Spares				14
3	Spares				20
4	Sea level pressure	mb	(46,72)	R*4	3312
5	Surface temperature	K	(46,72)	R*4	3312
6	Tropopause pressure	mb	(46,72)	R*4	3312
7	Relative humidity	(%)	(46,72,6)	R*4	19872
	Record No. 2				
1	U wind component	m/s	(46,72,12)	R*4	39744
	Record No. 3				
1	V wind component	m/s	(46,72,12)	R*4	39744
	Record No. 4				
1	Temperature	m/s	(46,72,12)	R*4	39744
	Record No. 5				
1	Geopotential height	(m)	(46,72,12)	R*4	39744

4.6.7 DSRN 81, 82, 83, 84, 85 and 86: Level II-b Data

The format for the international exchange of FGGE Level II data may be seen in the report prepared by the Working Group on the Global Data Processing System (1979).

4.6.8 DSRN 25: Level II-a Data

Item number	Data element	Type	Number of words
1	TAU	R*4	1
2	Year, Month, Day, Hour (GMT)	I*4	4
3	File name (8 elements)	L*1	2
4	Number of reports	I*4	1
5	Number of elements in data array	I*4	1
6	Data array (1)	I*2	(Item number 5)

A description of the data unpacking routines may be seen in Edelmann (1979).

4.6.9 DSRN 40: Surface Albedo

Item number	Data element	Type	Number of words
1	Surface albedo	I*2	3312

4.8.10 DSRN 87: Satellite Temperature Sounding Data (NESS Operational TIROS-N and VTPR)

Item number	Data element	Type	Number of words
1	TAU	R*4	1
2	Satellite ID 1=TIROS-N 2=VTPR	I*4	1
3	Latitude	R*4	1
4	Longitude (positive west of Greenwich)	R*4	1
5	Zenith angle	R*4	1
6	Elevation of surface (10^{-6} m)	R*4	1
7	Skin temperature (K)	R*4	1
8	Estimated surface pressure (mb)	R*4	1
9	Instrument/channel combination*	I*4	1
10	Retrieval method**	I*4	1
11	Spares		3
12	Tropopause pressure (mb)	R*4	1
13	Tropopause temperature (K)	R*4	1
14	Spares		5
15	Dry bulb temperature (K)	R*4	12
16	Geopotential height (m)	R*4	12
17	Virtual temperature (K)	R*4	12

*ICC = 10000*V + 1000 * W + 100 * X + 10 * Y + Z

**MR = 100*X + 10*Y + Z

4.6.11 DSRN xx: FGGE Special Effort TIROS-N Retrievals

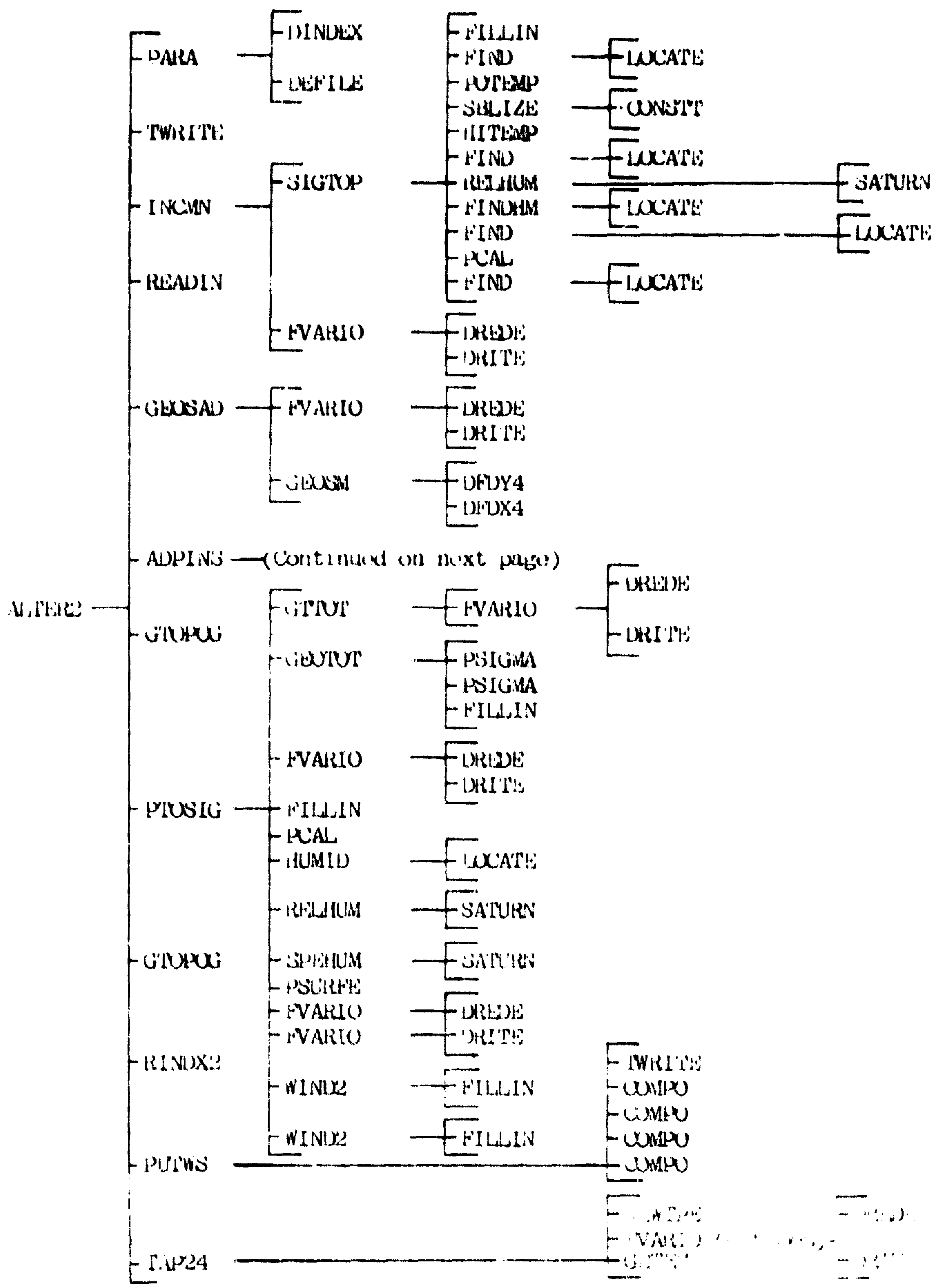
Item number	Data element	Type	Number of words
1	TAU	R*4	1
2	Year, Month, Day, Hour (GMT)	I*4	4
3	Data source index	I*4	1
4	Report identification	R*4	2
5	Latitude	R*4	1
6	Longitude (0° to 360° west of Greenwich)	I*4	1
7	Hour of observation	I*4	1
8	Minute of observation (10^{-2} h)	I*4	1
9	Instrument type	I*4	1
10	Special effort quality flag	I*4	1
11	Surface elevation (m)	R*4	1
12	Surface pressure (mb)	R*4	1
13	Surface temperature (°C)	R*4	1
14	Surface dew-point depression (°C)	R*4	1
15	Sea level pressure (mb)	R*4	1
16	Skin temperature (°C)	R*4	1
17	Solar zenith angle -90°(night) to +90°(day)	I*4	1
18	Channel combination	I*4	1
19	Standard deviation for low-level channel 7	I*4	1
20	Standard deviation for medium-level channel	I*4	1
21	Value of NSTAR (N^{*}*1000)	I*4	

4.6.11 Continued

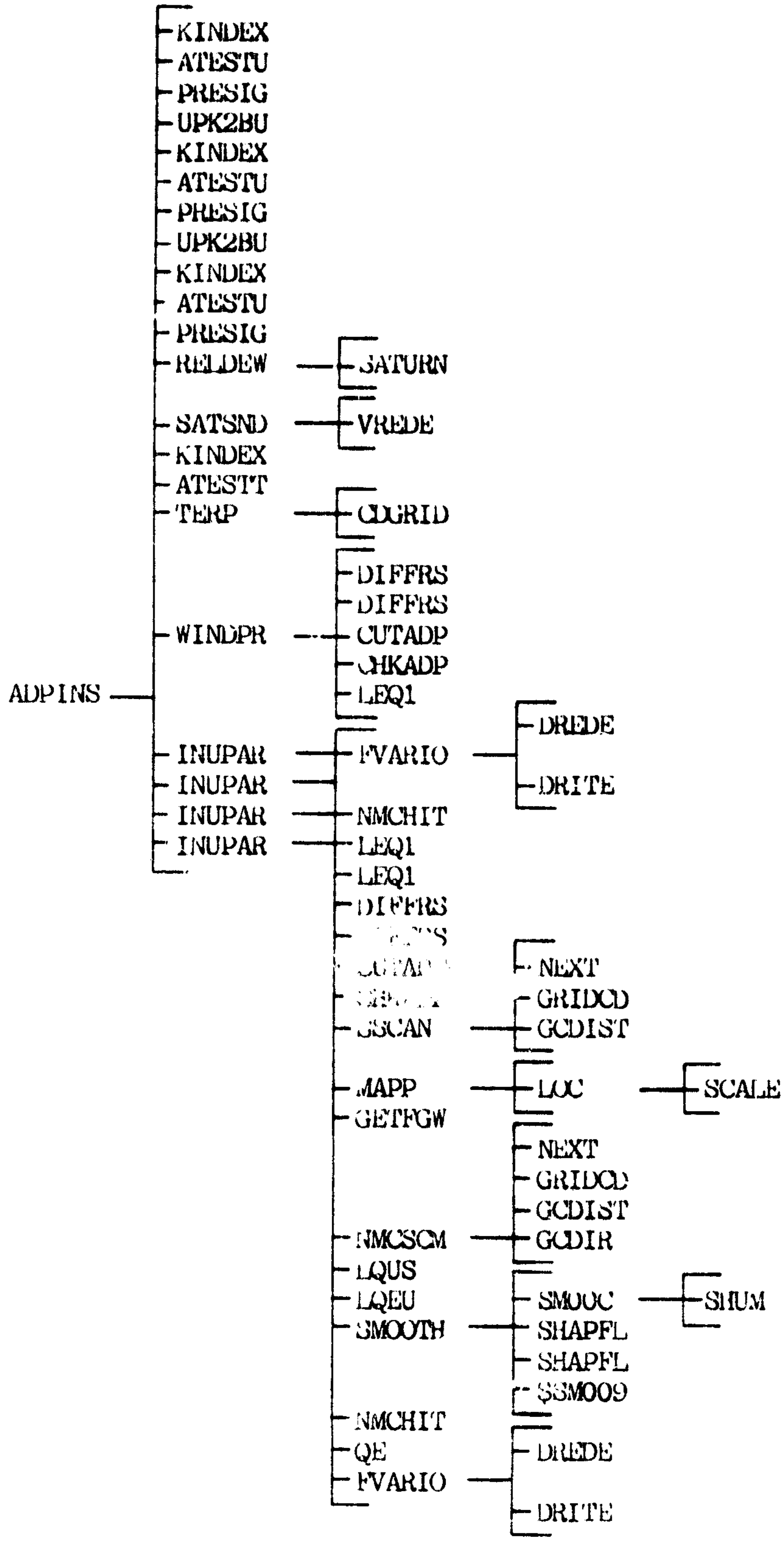
Item number	Data element	Type	Number of words
22	Retrieval Method	I*4	1
23	Orbit line number	I*4	1
24	Scan element number	I*4	1
25	Pressure of average cloud top (10 mb)	I*4	1
26	Cloud cover (%)	I*4	1
27	Total ozone (Dobson Units)	I*4	1
28	Tropopause pressure (10 mb)	I*4	1
29	Tropopause temperature (10 °C)	I*4	1
30	Quality indicator for tropopause pressure	I*4	1
31	Layer mean temperature (°C)	R*4	15
32	Layer precipitable water (mm)	R*4	3
33	Quality indicator for temperature (not used)	I*4	15
34	Quality indicator for precipitation (not used)	I*4	3
35	Mandatory level heights (1000-10 mb in m)	R*4	15
36	Mandatory level temperature (850-10 mb in °C)	R*4	14
37	Mandatory level dew point (850-10 mb in °C)	R*4	5

5. Program Logic and Subroutine Description

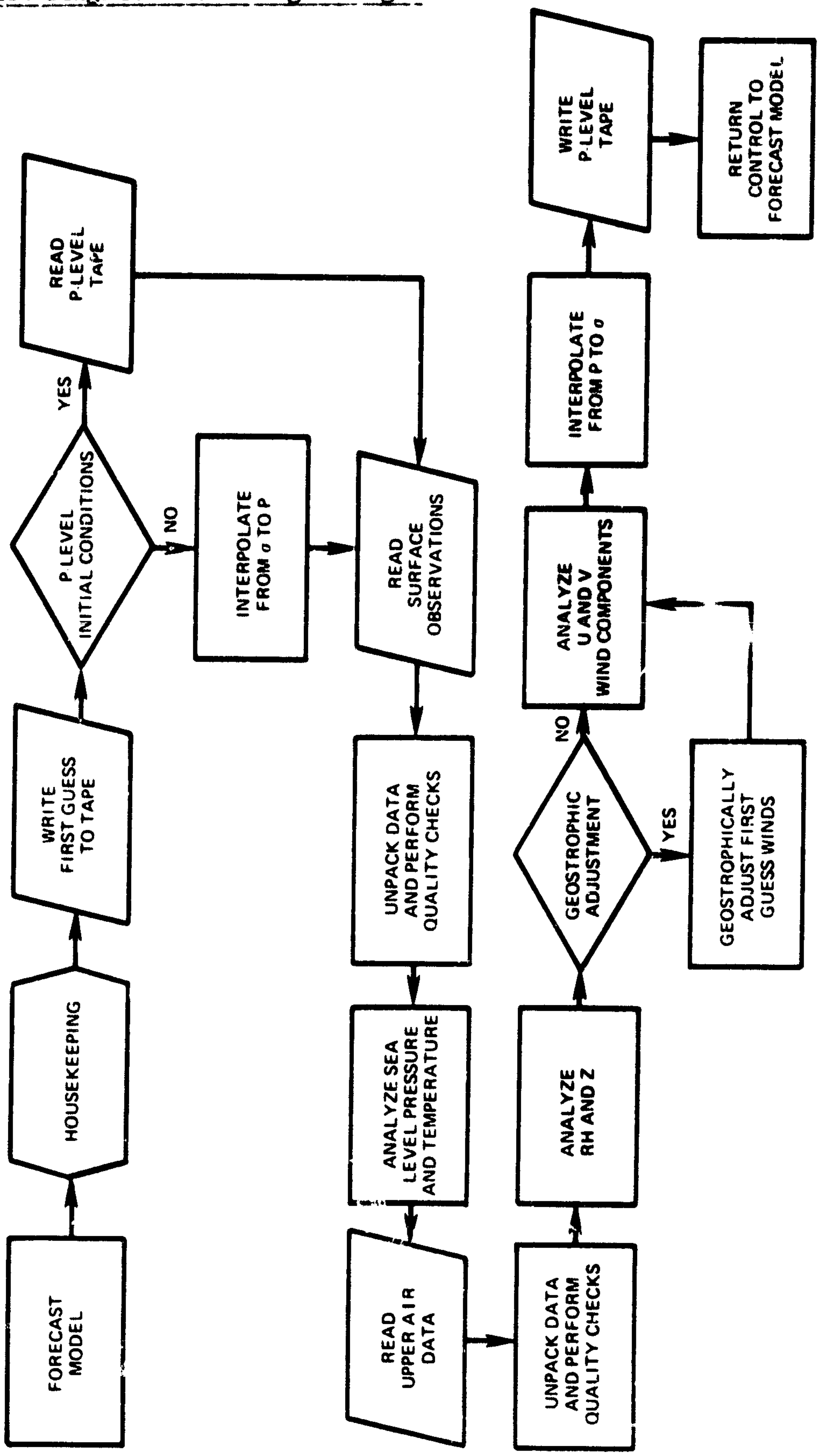
5.1 Subroutine Calling Sequence



- ADPINS
  - LEQ1
  - UPKST3
  - KINDEX
  - ATESTP
    - DIFFRS
      - TERP
        - CDGRID
  - UPK2BB
  - KINDEX
  - INSEAL
  - INSURF
    - FVARIO
      - DREDE
      - DRITE
    - LEQ1
    - DIFFRS
    - CUTADP
    - CHKADP
    - SSCAN
      - NEXT
      - GRIDCD
      - GRDIST
    - MAPP
      - LOC
        - SCALE
    - GETFGW
    - NMCSCM
      - NEXT
      - GRIDCD
      - GCDIST
      - GCDIR
    - LQUS
    - LQEU
    - SMOOTH
      - SMOOC
        - SHUM
      - SHAPFL
      - SHAPFL
      - $SM009
    - FVARIO
  - LEQ1
  - UPKST5
  - KINDEX
  - QE
  - TERP
    - CDGRID
  - ATESTQ
    - LEQ1
  - ATESTH
  - ATESTA
  - LEQ1
  - UPKST5
  - KINDEX
  - ATEST3
    - LEQ1
  - FINDLV
    - TERP
      - CDGRID
    - GETWND
  - LEQ1
  - UPKST5
  - KINDEX
  - PAIRZ
  - PRESIG
  - GETAHT
    - TERP
      - CDGRID
  - UPK2BW
  - KINDEX
  - ATESTW
  - PRESIG
  - UPK2BW
  - KINDEX
  - ATESTW
  - PRESIG
  - UPK2BU
  - (Continued on next page)


ADPINS
KINDEX
ATESTU
PRESIG
UPK2BU
KINDEX
ATESTU
PRESIG
UPK2BU
KINDEX
ATESTU
PRESIG
RELDEW
SATURN
SATSND
VREDE
KINDEX
ATESTT
TERP
CDGRID
WINDPR
DIFFRS
DIFFRS
CUTADP
CHKADP
LEQ1
INUPAR
INUPAR
INUPAR
INUPAR
FVARIO
DREDE
DRITE
NMCHIT
LEQ1
LEQ1
DIFFRS
NEXT
GRIDCD
GCDIST
SSCAN
MAPP
LOC
SCALE
GETFGW
NEXT
GRIDCD
GCDIST
GCDIR
NMCSCM
LQUS
LQEU
SMOOC
SHUM
SMOOTH
SHAPFL
SHAPFL
$SMOO9
NMCHIT
QE
FVARIO
DREDE
DRITE

5.2 Flow Diagram of the Program Logic



5.3 Subroutine Description

This section contains a detailed description of each subroutine in the objective analysis program. Unless otherwise indicated the information is appropriate for the objective analysis with the 4° x 5° 4th order model.

SUBROUTINE ADPINS   Argument list: None

Description: Performs objective analysis of sea level pressure and temperature and humidity, wind, and geopotential height at the 12 mandatory pressure levels; called by ALTER2.

The routine also reads in all observational data, checks for time, report type, and quality marks, stores appropriate values in COMMON, and calls respective SCM analysis routines to modify model quantities.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S[1]	F[2]	A[3]	Description

None

Common areas	Length	Description
CNTRL	D50	4th order model parameters
SATRET	54	Satellite retrieval DSRN
PHYSIC	20	Physical constants
QTYPE	4	Quantity analyzed; set in ALTER2
ADPTYP	C	Analysis parameters
FACOMM	107800	Analysis arrays
ADPQWT	5DC4	Data quality weights
INDEX1	320	Report type descriptions
INDEX2	64	Report Type flags

External references	Description
QE	Indefinite logical comparison
LEQ1	Single logical comparison
TERP	Horizontal bilinear interpolation
PAIRZ	Aircraft pressure calculation
ATESTH	Hydrostatic check
ATESTP	Sea level pressure check (bogus if necessary)
ATESTQ	Tests quality marks
ATESTU	Tests upper air II-b quality marks
ATESTT	Tests TIROS-N quality marks
ATESTW	Tests Wisconsin wind II-b quality marks
ATEST3	Category 3 report check
FINDLV	Variable pressure wind interpolation
GETAHT	Aircraft height calculation
INSEAL	Sea level pressure SCM
INSURF	Sea level temperature SCM
INUPAR	Upper air SCM
KINDEX	Report index identifier
PRESIG	Mandatory pressure level sigma calculation
RELDEW	Relative humidity calculation
UPKST3/UPKST5	II-a unpacker for surface/upper air
UPK2BB/UPK2BU/UPK2BW	II-b unpacker for buoy/upper air/Wisconsin winds

SUBROUTINE ADPINS (Continued)

WINDPR	Wind vector error check
SATSND	Reads satellite soundings

Input/Output ddname	I	O	Method	Description
25	X		U seq.	II-a ADP data
LUSAT(1),...,LUSAT(NSAT)	X		U seq.	Satellite retrievals
81	X		F seq.	Drifting buoys
82	X		F seq.	Wisconsin East and West
83	X		F seq.	Wisconsin Indian Ocean
84	X		F seq.	Constant level balloons
85	X		F seq.	NAVAIDS
86	X		F seq.	Dropwindsondes

[1] Stored

[2] Fetched

[3] Addressed

SUBROUTINE ALTER2 Argument list: None

Description: Driver routine for the 4th order objective analysis, called by MAIN. This routine interpolates the first guess to the pressure levels, performs geostrophic adjustment if necessary, performs objective analysis, interpolates analyzed fields to the σ levels, and restores new values to the model. ALTER2 also performs dynamic initialization if necessary.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description

None

Common areas	Length	Description
CNTRL	D50	4th order model parameters
QTYPE	4	Data flag set in the main loop
ALPUT	10	Analysis control parameters
CYCLE	C	Dynamic inialization parameters
GEOS1	4	Geostrophic adjustment flag
INS	4	
INMAP	4	Map Index
FGQWT	4	First guess quality weights

External references	Description
PARA	Initializes parameters and reads namelist
INCMN	Interpolates model σ values to pressure levels
PUTWS	Dynamic initialization restoring cycle
ADPINS	Performs objective analysis
GEOSAD	Geostrophic wind adjustment
READIN	Reads mandatory level initial conditions
RINDX1	Fetches model quantities, reversing dimensions
RINDX2	Saves model quantities, reversing dimensions
TWRITE	Writes model σ values to tape
TAP24	Log 24 tape

SUBROUTINE ALTER2 (2.5° x 3° 2nd Order Model) Argument list: None

Description. Driver routine for the 2.5° x 3° 2nd order objective analysis, called by MAIN.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description

None

Common areas	Length	Description
SPLIT	24	Split-grid flags
ALPUT	8	Control flags
GEOS1	4	Geostrophic adjustment flag
TSANG	1244160	Model σ quantities
PHYSIC	72	Physical constants
QTYPE	4	Quantity flag
SDOT48	17760	Diagnostic quantities

External references	Description
RD1	Reads model quantities from direct-access disk
REW	Rewinds tape
PARA	Initializes parameters for analysis
WRTP	Writes mandatory-level output to tape
WRT1	Writes model quantities to direct-access disk
INCMN	Interpolates model σ quantities to mandatory levels
RDSDT	Reads diagnostic quantities from disk
WTSDT	Writes diagnostic quantities to disk
ADPINS	Reads observational data and performs analysis
CLOCKS	CPU timer
GEOSAD	Geostrophic adjustment of winds
PTOSIG	Interpolates analyzed fields back to σ levels
RDISK2	Reads temporary disk
READIN	Reads mandatory-level initial conditions
TWRITE	Writes model σ quantities to tape
UNSP2D	Unsplits model quantities
UNSP3D	Unsplits model quantities
WDISK1	Writes temporary disk

Input/Output ddname	I	O	Method	Description
25	X	X	U seq.	LEVEL 2A data
8	X	X	U seq	History tape
33	X	X	U seq.	Temporary storage for diagnostic quantities
21	X	X	U seq.	Mandatory-level initial conditions
47	X	X	U seq.	Surface quantities

18	X	X	DA	Model σ quantities
24	X	X	U seq.	Pressure-level output tape
22	X	X	U seq.	Temporary disk

SUBROUTINE ATESTA Argument list: NL, P, T, KB, *

Description: Tests observational temperature profile for stability; sometimes called by ADPINS.

Restrictions: Profile runs from surface to top of atmosphere.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
NL	I*4			X		Number of levels in profile (at least 2)
P	R*4	NL		X		Observed pressures
T	R*4	NL		X		Observed temperatures
KB	I*4		X	X		Rejected profile counter
*						Rejected profile return

Common areas	Length	Description
PHYSIC	20	Physical constants

SUBROUTINE ATESTH   Argument list: NL, P, Z, T, KB, *

Description. Performs hydrostatic check on observational temperature profile, called by ADPINS.

Restrictions: Profile runs from surface to top of atmosphere.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
NL	I*4			X		Number of levels in profile (at least 2)
P	R*4	NL		X		Observed pressures
Z	R*4	NL		X		Observed heights
T	R*4	NL		X		Observed temperatures
KB	I*4		X	X		Rejected profile counter
*						Rejected profile return

Common areas	Length	Description
PHYSIC	20	Physical constants

SUBROUTINE ATESTP Argument list: CD, PSL

Description: Tests sea level pressure against first guess for possible erroneous entries and boguses them when necessary, called by ADPINS.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
CD	R*4	2		X	X	Earth coordinates of report
PSL	R*4		X	X	X	Sea level pressure

Common Areas	Length	Description
MODEL	7E240	Model first guess arrays
CNTRL	D50	4th order model parameters

External References	Description
DIFFRS	Computes difference between observation and model

SUBROUTINE ATESTQ Argument list. NL, ML, TEST, X, KB

Description: Tests level II-a data quality marks, called by ADPINS.

Restrictions: Quality marks are as returned by UPKST5 unpacker. ADP data filled with 99999., if poor quality.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
NL	I*4			X		Number of levels
ML	I*4					Dimension of arrays
TEST	R*4	ML		X		Quality mark array
X	R*4	(ML,5)	X			Data array
KB	I*4	5	X	X		Rejected report counter

Common areas	Length	Description
None		

External references	Description
LEQ1	Single logical comparison

SUBROUTINE ATESTT Argument list. KTSN, *

Description. Tests TIROS-N quality marks, filled either operationally or interactively on McIDAS, called by ADPINS.

Restrictions. None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
KTSN	I*4			X		Quality mark return for poor quality
*						

SUBROUTINE ATESTU Argument list: NL, ML, KTEST, X, KB

Description: Tests upper air Level II-b quality marks, called by ADPINS.

Restrictions: Quality marks are as returned by UPK2BU unpacker.
Data filled with 99999., if poor quality.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
NL	I*4			X		Number of levels
ML	I*4					Dimension of arrays
KTEST	I*4	(ML,5)		X		Quality mark array
X	R*4	(ML,5)	X			Data array
KB	R*4		X	X		Rejected report counter

SUBROUTINE ATESTW Argument list: KWAL, KB, *

Description: Tests Wisconsin wind quality marks, called by ADPINS.

Restrictions: Quality marks are returned by UPK2BB unpacker.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
KWAL	I*4			X		Quality mark
KB	I*4		X	X		Rejected report counter
*						Rejected report return

SUBROUTINE ATEST3 Argument list: TEST, KAT, *

Description. Tests Category 3 identifier marks for category as well as quality, called by ADPINS.

Restrictions. Quality marks are returned by the UPKST5 unpacker.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
TEST	L*1	4			X	Identifier mark
KAT	I*4		X			Category returned = 1. CAT1 = 2. CAT3
*						Rejected report return

Common areas	Length	Description
None		

External references	Description
LEQ1	Single logical comparison

SUBROUTINE CDGRID   Argument list: CD, X

Description: Computes earth coordinates of the 4th order grid points.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
CD	R*4	2		X		Earth coordinates
X	R*4	2	X			Grid points returned

SUBROUTINE CHKADP Argument list. NS, KQ, L

Description: Performs lateral "buddy" check on rejected reports, called by INSEAL, INSURF, INUPAR, and WINDPR.

This routine averages all reports within a 5° radius of the rejected reports. If there are at least 3 of these reports and the difference between the rejected report and the average differences is within the cutoff criteria, the report is accepted.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
NS	I*4			X		Total number of stations
KQ	I*4			X		Quality flag
L	I*4			X		Pressure level

Common areas	Length	Description
FACOMM	107800	4th order analysis arrays
ADPSC	8	Surface error criteria
ADPUC	5000	Upper air error criteria
OBSRNT	1200	Observed RMS storage area
INDEX1	320	Report type description

External references	Description
LEQ1	Single logical comparison

SUBROUTINE CLOCKS Argument list: I

Description. This routine allows the user to determine the time elapsed in execution.

Restrictions. None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
I	I*4					The amount of elapsed execution time.

SUBROUTINE CONSTT Argument list TS, P, LA, LB

Description: Performs a dry-convective adjustment on a temperature profile.

Restrictions. None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
TS	R*4	11	X	X		Potential temperature profile
P	R*4	12		X		Edge pressue profile
LA	I*4			X		Lower level of layer
LB	I*4			X		Upper level of layer

SUBROUTINE CUTADP Argument list KX,CD,VALA,DIF,CUT,RMS,IRMS,RMSX,IRMSX, FLA

Description. Finds the difference between the observation and the first guess and compares the difference with the cutoff criteria, called by INSEAL, INSURF, INUPAR, and WINDPR.

Restrictions: A report flag is filled with .FALSE. if it is an allowable difference. It is filled with a "C" if it is not an allowable difference but within 3 times the allowable difference and with an "R" otherwise.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
KX	I*4	2		X		Report type
CD	R*4			X		Earth coordinates
VALA	R*4			X		Reported data
DIF	R*4			X		Difference from model
CUT	R*4			X		Error criteria
RMS	R*8		X	X		RMS of accepted data
IRMS	I*4		X	X		Number of accepted reports
RMSX	R*8		X	X		RMS of rejected data
IRMSX	I*4		X	X		Number of rejected reports
FLA	L*1		X			Report flag

Common areas	Length	Description
INDEX1	320	Report-type descriptions

SUBROUTINE DEFILE Argument list: IDSRN, MAXREC, MAXLTH, ITYPE, IAVER, IOK

Description: This routine performs DEFINE FILE functions, which must be done before using direct access I/O on a SSS dataset.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
IDSRN	I*4					Dataset reference number
MAXREC	I*4					Maximum number of records in the dataset
MAXLTH	I*4					Maximum length of a record
ITYPE	I*4					Type of variable
IAVER	I*4					The associated variable
IOK	I*4					Variable returned

SUBROUTINE DFDX4, DFDY4 Argument list: J, JM, I, IM, F, D

Description: Directional derivative of a two-dimensional field by 4th order differencing, called by GEOSM.

Restrictions. None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
DFDX4	R*4		X			X direction derivative returned
DFDY4	R*4		X			Y direction derivative returned
J	I*4			X		Y grid point
JM	I*4			X		Y grid maximum
I	I*4			X		X grid point
IM	I*4			X		X grid maximum
F	R*4	(JM, IM)		X		Horizontal field
D	R*4			X		Distance between grid points

SUBROUTINE DIFFRS   Argument list. JM, IM, CD, D, F, DIF

Description. Finds difference between observation at arbitrary earth coordinates and a two-dimensional model field using bilinear interpolation.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
JM	I*4				X	Latitudinal dimension
IM	I*4				X	Longitudinal dimension
CD	R*4	2			X	Earth coordinates of observation
D	R*4			X		Observational value
F	R*4	(JM, IM)			X	Horizontal model field
DIF	R*4		X			Difference returned

Common areas	Length	Description
None		

External references	Description
TERP	Bilinear horizontal interpolation of model field

SUBROUTINE DREDE Argument list: LU, ISEG, JBUF, IRET

Description: SSS D/A read routine

Restrictions. None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
LU	I*4					Logical unit number of file
ISEG	I*4					Segment number
JBUF	I*4					Buffer to pass data
IRET	I*4					Return code
MSEG	I*4					

SUBROUTINE DRITE Argument list: LU, ISEG, JBUF, MSEG, IRET

Description: SSS D/A write routine

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
LU	I*4					Logical unit number of file
ISEG	I*4					Segment number
JBUF	I*4					Buffer to pass data
IRET	I*4					Return code
MSEG	I*4					

SUBROUTINE DUMMYZ,INSMIT,PTHCOA Argument list: None

Description. Dummy returns to replace previously used routines.

Restrictions: None

SUBROUTINE FILLIN Argument list: P

Description: Computes σ-edge pressures given the surface and top pressure; called by SIGTOP.

Restrictions: Profile is bottom to top. P(1) must be pre-loaded with surface pressure and P(10) must be pre-loaded with the top pressure.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
P	R*4	10	X	X		σ-edge pressures

SUBROUTINE FIND Argument list: PA, P, X, KEY

Description: Interpolates linear in log p a σ-level profile to any desired pressure; called by SIGTOP.

Restrictions: Set KEY=0 to avoid extrapolation.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
FIND	R*4		X			Interpolated value returned
PA	R*4			X		Desired pressure
P	R*4	9		X		σ-level pressure
X	R*4	9		X		σ-level data
KEY	I*4			X		Extrapolation flag

Common areas	Length	Description
None		

External references	Description
LOCATE	Finds the σ-level pressures which straddle a given p level

SUBROUTINE FINDHM Argument list: PA, P, H, KEY

Description: Interpolates linear in log p a humidity σ-level profile to any desired pressure; called by SIGTOP.

Restrictions: Set KEY=1 to restrict relative humidity to between 0.01 and 1.0. Set KEY=0 for specific humidity interpolation.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
FINDHM	R*4		X			Interpolated humidity
PA	R*4			X		Desired pressure
P	R*4	9		X		σ-level pressures
H	R*4	9		X		σ-level humidity
KEY	R*4			X		Humidity units flag

SUBROUTINE FINDLV Argument list: CD, NLEV, X1, X2, X3, X4, X5, KEY

Description: Interpolates variable pressure Category (pilot balloon) wind reports to mandatory pressure levels; called by ADPINS. If height is given rather than pressure, the model first guess height is used for interpolation.

Restrictions: Profile must be ordered from bottom to top. Set KEY=1 if height is given or set KEY=2 if pressure is given.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
CD	R*4	2		X	X	Earth coordinates
NLEV	I*4			X	X	Number of levels in profile
X1	R*4	20	X		X	U wind returned
X2	R*4	20		X	X	Height or pressure
X3	R*4	20	X		X	V wind returned
X4	R*4	20		X	X	U wind profile
X5	R*4	20		X	X	V wind profile
KEY	I*4			X		Height/pressure flag

Common areas	Length	Description
MODEL	7E240	Model first guess arrays

External references	Description
TERP	Performs bilinear horizontal interpolation of first guess
GETWND	Performs vertical interpolation of wind profile

SUBROUTINE FVARIO Argument list: LU, IO, LEVEL, JBUF

Description. This routine performs the direct access I/O of two-dimensional 4° x 5° records.

Restrictions: The dataset must be RECFM=F, LRECL=372, DSORG=DA and must be initialized by CALL DEFILE (LU, MSEG, 1080, 2, LP, IRET), where MSEG=36* (number of levels). The number of levels cannot exceed (35/36)* (tracks in dataset).

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
LU	I*4				X	Logical unit number
IO	I*4			X		I/O flag,=0 for read, =1 for write
LEVEL	I*4			X		4° x 5° record number
JBUF	I*4	1	X	X	X	4° x 5° array

Common areas	Length	Description
None		

External references	Description
DREDE	SSS direct access read
DRITE	SSS direct access write

Input/Output ddname	I	O	Method	Description
LU	X	X	SSS DA	4° x 5° record direct-access

SUBROUTINE GCDIR Argument list: P, Q

Description. This routine determines the direction from one point on the Earth along a great circle to another point on the Earth. The direction is returned as an angle between 0° and 360° (0 represents north and 90 east.

Restrictions: The direction is returned as 0 if the great circle cannot be determined.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
GCDIR	R*1		X			Direction returned
P	R*4	2		X		Origin point in earth coordinates
Q	R*4	2		X		End point in earth coordinates

Common areas	Length	Description
PHYSIC	20	Physical constants

SUBROUTINE GCDIST   Argument list. P, Q

Description: Determines the distance from one point on the Earth along a great circle to another point on the Earth.

Restrictions. None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
GCDIST	R*4		X			Distance returned
P	R*4	2		X		Origin point in earth coordinates
Q	R*4	2		X		End point in earth coordinates

SUBROUTINE GEOSAD   Argument list. None

Description: Performs a geostrophic adjustment on the first guess wind field based on an analysis of the geopotential height field, called by ALTER2.

Restrictions: The first guess geopotential height field must be on direct-access disk.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description

None

Common areas	Length	Description
MODEL	7E240	First guess winds and analyzed heights
FACOMM	3300	Work array for height corrections

External references	Description
FVARIO	Direct-access I/O utility
GEOSM	Geostrophic adjustment at the mandatory levels

Input/Output ddname	I	O	Method	Description
23	X		SSS DA	Analysis direct-access file

SUBROUTINE GEOSM   Argument list L, DZ, U, V

Description: GEOSM performs a geostrophic adjustment of the first guess wind field.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
L	I*4			X		Mandatory level
DZ	R*4	(46,72)		X	X	First guess height differences
U	R*4	(46,72)	X	X		U-Component
V	R*4	(46,72)	X	X		V-Component

Common areas	Length	Description
PRINT1	54	Sample gridpoints for printout
GEDS1	318	Constants and constraints for geostrophic adjustment
PHYSIC	4	Physical constant

External references	Description
DFDX4	4th order X-direction derivative
DFDY4	4th order y-direction derivative

SUBROUTINE GEOTOT Argument list: None

Description: Interpolates σ-level ΔT from mid-mandatory level ΔT and adds σ-level ΔT to first guess σ-level temperature to obtain updated temperature. Computes potential temperature to perform a convective adjustment and finally converts to temperature; called by PTOSIG.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description

None

Common areas	Length	Description
CNTRL	82350	Model parameters
MODEL	7E240	Model arrays
PHYSIC	14	Physical constants
PMID	2C	Mid-mandatory level pressure
PRMAND	30	Pressure level constants

External references	Description
FILLIN	Computes σ-edge pressures
PSIGMA	Determines mid-layer σ pressure

SUBROUTINE GETAHT Argument list: CD, ALT, PA, TZ, LM, ZZ

Description: Creates pseudo height profile from an aircraft temperature report and the model first guess height field; called by ADPINS. The height profile extends above the aircraft report only and is not computed below the aircraft level.

Restrictions: The profile runs from top to bottom

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
CD	R*4	2		X	X	Aircraft earth coordinates
ALT	R*4					Altitude (not used)
PA	R*4			X	X	Aircraft pressure
TZ	R*4			X		Aircraft temperature
LM	I*4			X		Lowest level desired
ZZ	R*4	12	X			Height profile returned

Common areas	Length	Description
CNTRL	D50	Model parameters
MODEL	7E240	Model first guess arrays
PRMAND	30	Mandatory level constants
PRMANM	2C	Mid-mandatory level constants
PHYSIC	20	Physical constants

External references	Description
TERP	Bilinear horizontal interpolation of first guess

SUBROUTINE GETEMP   Argument list: ZP, TP

Description: Computes mandatory level temperatures; called by TAP24.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
ZP	R*4	(46,72,12)				Height field
TP	R*4	(46,72,12)				Temperature field

Common areas	Length	Description
PHYSIC	20	Physical constants

SUBROUTINE GETFGW Argument list: KQ, L, FGW

Description. GETFGW reads in first guess weights for a given quantity and level, called by INSEAL, INSURF, and INUPAR.

Restrictions. None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
KQ	I*4			X		Data type (1-6)
L	I*4			X		Level (1-12)
FGW	R*4	(46,72)	X		X	Weights array

Common areas	Length	Description
None		

External References	Description
FVARIO	Direct access I/O of 4° x 5° records

Input/Output ddname	I	O	Method	Description
61	X		SSS DA	Dataset containing first guess weights

SUBROUTINE GETWND Argument list: NLEV, PA, PL, NL, X1, X3, X4, X5

Description: Performs a linear vertical interpolation of a variable pressure wind profile to mandatory levels; called by FINDLV.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
NLEV	I*4			X		Number of input levels
PA	R*4	20		X		Input pressure
PL	R*4	12		X		Output pressure
NL	I*4	20				Not used
X1	R*4	20	X			Output u wind
X3	R*4	20	X			Output v wind
X4	R*4	20		X		Input u wind
X5	R*4	20		X		Input v wind

SUBROUTINE GRIDCD Argument list: JI, X

Description: Converts a 4th order grid point to earth coordinates

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
JI	I*4	2		X		Grid point
X	R*4	2	X			Earth coordinates

SUBROUTINE GTOPOG Argument list: IDSRN

Description: Reads topography values which are different from those used by the model; called by ALTER2.

Restrictions: When the variable IDSRN in the argument list is less than or equal to zero, a return is executed and the read is bypassed.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
IDSRN	I*4			F		Data Set Reference Number

Common areas	Length	Description
MODEL	7E240	Model first guess arrays

External references	Description
None	

Input/Output ddname	I	O	Method	Description
IDSRN	X		Seq.	SSS Sequential

SUBROUTINE GTTOT Argument list: None

Description: Computes mid-mandatory level ΔT; called by PTOSIG.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description

None

Common areas	Length	Description
CNTRL	D50	Model parameters
MODEL	7E240	Model analyzed fields
PHYSIC	20	Physical constants
PRMAND	60	Mandatory level constants

SUBROUTINE HITEMP   Argument list: TS, P, Z

Description: Computes mandatory level geopotential height given the 1000 mb height, mandatory-level pressure and mid-mandatory level temperature.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
TS	R*4	11		X		Mid-mandatory level temperatures
P	R*4	12		X		Mandatory level pressure
Z	R*4	12	X			Mandatory level height

Common Areas	Length	Description
PHYSIC	20	Physical constants

SUBROUTINE HUMID Argument list: PA, P, H, KEY

Description: Performs a linear in log p interpolation of a mandatory-level relative humidity profile to the σ-levels; called by PTOSIG.

Restrictions: Set KEY=1 to restrict the relative humidity between 0.01 and 1.0.
Set KEY=2 for interpolation of ΔRH.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
HUMID	R*4		X			Interpolated humidity
PA	R*4	12		X	X	Pressure profile
P	R*4			X	X	σ-level pressure
H	R*4	12		X		Humidity profile
KEY	I*4			X		Humidity flag

SUBROUTINE INCMN Argument list: None

Description: Fills model arrays for analysis by vertical interpolation (using SIGTOP) from 4th order σ-levels; called by ALTER2.

Restrictions: Array T (J,I,12) is filled with 1000 mb height.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description

None

Common areas	Length	Description
CNTRL	D50	Model parameters
MODEL	7E240	Model arrays
QTYPE	4	Data flag from ALTER2
CYCLE	C	Restoring cycle parameters

External references	Description
SIGTOP	Single profile vertical interpolation

SUBROUTINE INSEAL Argument list: NS

Description: Sea level pressure SCM analysis; called by ADPINS.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
NS	I*4			X		Number of stations

Common areas	Length	Description
PHYSIC	28	Physical constants
ADPTYP	18	Analysis parameters
SCM2	18	SCM parameters
CNTRL	D50	Model parameters
PRINT1	54	
MODEL	9B40	Model arrays
FACOMM	140300	Analysis arrays
ADPSC	8	Sea level error limits
SMOOTS	18	Smoothing parameters
OBSKNT	1200	RMS storage area
FGQWT	33C4	First guess weights
ADPQWT	5DC4	ADP quality weights
INDEX1	320	Data type

External references	Description
LEQ1	Single logical comparison
LQEU	Europe grid point determinant
LQUS	United States grid point determinant
SSCAN	Station counting scanner
CHKADP	Horizontal buddy check
CUTADP	Check for observation and model difference
DIFFRS	Difference between observation and model
FVARIO	Direct access I/O for 4° x 5° records
NMCSCM	SCM accumulating scanner
SMOOTH	4° x 5° field smoother

Input/Output ddname	I	O	Method	Description
23		X	SSS DA	Temporary direct-access dataset for the first guess and analysis

SUBROUTINE INSURF Argument list: NS

Description: Sea level temperature SCM analysis; called by ADPINS.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
NS	I*4			X		Number of stations

Common areas	Length	Description
(Same as INSEAL)		

External references	Description
(Same as INSEAL)	

Input/Output ddname	I	O	Method	Description
(Same as INSEAL)				

SUBROUTINE INUPAR Argument list: NS, KQ

Description: Upper air SCM analysis; called by ADPINS.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
NS	I*4			X		Number of stations
KQ	I*4			X		Quantity type

Common areas	Length	Description
(Same as INSEAL)		

External references	Description
QE	Indefinite logical comparison
LEQ1	Single logical comparison
LQEU	Europe grid point determinant
LQUS	United States grid point determinant
SSCAN	Station counting scanner
CHKADP	Horizontal buddy check
CUTADP	Check for observation and model difference
DIFFRS	Computes difference between observation and first guess
FVARIO	Direct access I/O for 4° x 5° records
NMCHIT	Geopotential height stability check
NMCSCM	SCM accumulating scanner
SMOOTH	4° x 5° field smoother

Input/Output ddname	I	O	Method	Description
23		X	SSS DA	Temporary direct-access dataset for the first guess and analysis

SUBROUTINE KINDEX, DINDEX   Argument list: CAT, STATN, DSI, INS, CD

Description. Report type identifier, called by ADPINS.

This routine tags a report with an index number determined from the data category, station ID, data source index, instrument type, and earth coordinates. Each separate report type corresponds to a different set of qua weights.

Restrictions: A zero is returned if the report is unrecognizable.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
KINDEX	I*4		X			Report index
CAT	L*1			X		Category
STATN	L*1	8		X		Station ID
DSI	I*4			X		Data source index
INS	I*4			X		Instrument type
CD	R*4	2		X		Earth coordinates
DINDEX	R*8		X			Report description

Common areas	Length	Description
None		

External references	Description
LEQ1	Single logical comparison

SUBROUTINE LEQ1 Argument list. A, B

Description. Compares two single byte characters. If they are the same, then LEQ1 returns. TRUE., otherwise it returns. FALSE.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
LEQ1	I*4		X			Logical comparison
A	L*1			X		Character 1
B	L*1			X		Character 2

SUBROUTINE LOC   Argument list: MAP, II, JJ, NX

Description: Selects the quantity to be plotted by testing the logical array QMAP; called by MAPP.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
MAP	I*4	(46,72)				
II	I*4	46				
JJ	I*4	72				
NX	I*4					

Common areas	Length	Description
QMP	50	Maximum number of maps

External references	Description
SCALE	Plots the quantity on a map
PRSCAL	Prints the scaled map

SUBROUTINE LOCATE   Argument list: PA, P, N

Description: Finds the pressures which straddle a given pressure level. Level returned is the level above the given pressure.

Restrictions: Profile must be ordered from bottom to top.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
LOCATE	I*4		X	X		Level returned
PA	R*4			X		Given pressure
P	R*4	N		X		Pressure profile
N	I*4			X		Number of levels

SUBROUTINE LQEU   Argument list: J, I

Description: Determines whether 4° x 5° grid point is over Europe. Europe is defined as the region from 38°N to 66°N and from 5°W to 30°E. LQEU is .TRUE. if the grid point falls in this region.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
LQEU	L*4		X			Logical flag returned
J	I*4			X		Latitudinal grid point
I	I*4			X		Longitudinal grid point

SUBROUTINE LQUS   Argument list: J, I

Description: Determines if a 4° x 5° grid point is over the United States. The United States is defined as the region from 26°N to 58°N and from 135°W to 80°W. LQUS is .TRUE. if the grid point falls in this region.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
LQUS	L*4		X			Logical flag returned
J	I*4			X		Latitudinal grid point
I	I*4			X		Longitudinal grid point

SUBROUTINE MAPP   Argument list: KNT

Description: Increments an integer variable which decides the pressure level at which the map is to be printed, This is called by INSEAL, INSURF and INUPAR.

Restrictions: None

Arguments and passed arrays	Type	Dimensions	S	F	A	Description
KNT		(46,72)				Araray of integers

Common areas	Length	Description
INMAP		Map number

External references	Description
LOC	Selects the map to be plotted

Input/Output ddname	I	O	Method	Description
None				

E-2

SUBROUTINE NEWTPE Argument list: NT2

Description: Sends message to operator to mount a new tape; called by TAP24.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
NT2	R*4					Logical unit number

SUBROUTINE NEXT Argument list: DMAX, CD, I, J, *

Description: NEXT is the grid point scanning routine; called by SSCAN and NMCSCM. This routine is used to efficiently scan all grid points within a given radius about a point on the Earth. NEXT is called repeatedly returning a single grid point each time until all points are read in the given radius.

Restrictions: Beware that conventional GLAS definitions of I and J are reversed. Also, all the points in a given radius should be read before moving to the next point.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
DMAX	R*4			X		Scanning radius in km
CD	R*4	2		X	X	Origin in earth coordinates
I	I*4		X	X		Latitudinal grid point returned
J	I*4		X	X		Longitudinal grid point returned
*						Return when scanning is complete

Common areas	Length	Description
BNDS	8	Latitudinal bounds
CNTRL	D50	Model parameters
PHYSIC	24	Physical constants

External References	Description
DGRID	Converts earth coordinates to grid points

SUBROUTINE NMCHIT   Argument list: NLEV, NITER

Description: Computes the model first guess height field; called by INUPAR.

Restrictions: Each level must be called in the order given in INUPAR.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
NLEV	I*4			X		Pressure level
NITER	I*4			X		SCM iteration number

Common areas	Length	Description
CNTRL	D50	Model parameters
FACOMM	107800	Analysis arrays
MODEL	7E240	Model arrays

SUBROUTINE NMCSUM Argument List: JM, IM, RITER, RADFAC, CD, DIF, QWT, WDIR, DEL, CNT, RAD

Description. Successive corrections accumulator, called by INSEAL, INSURF, and INUPAR. This routine accumulates the grid point corrections, applying the appropriate distance and quality weights. The wind correction is also dependent on direction with upstream and downstream observations given more weight than crosswind observations. The scanning radius is decided on density of stations about a grid point.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
JM	I*4			X		Latitude dimension
IM	I*4			X		Longitude dimension
RITER	R*4			X	X	Maximum iteration radius
RADFAC	R*4			X		Iteration distance factor
CD	R*4	2		X	X	Earth coordinates of observation
DIF	R*4			X		Observational and first guess difference
QWT	R*4			X		Observational quality weight
WDIR	R*4			X		Observational wind direction
DEL	R*4	(JM, IM)	X	X		Corrections array
CNT	R*4	(JM, IM)	X	X		Weights array
RAD	R*4	(JM, IM)		X		Radii array

Common areas	Length	Description
PHYSIC	20	Physical constants

External references	Description
NEXT	Grid point scanner
GCDIR	Great circle direction calculation for elliptical weighting
GCDIST	Great circle distance calculation
GRIDCD	Converts grid points to earth coordinates

SUBROUTINE PAIRZ Argument list: AZ

Description: Computes aircraft pressure from reported pressure altitude and U.S. standard heights; called by ADPINS. The height interpolation is linear in log p.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
PAIRZ	R*4		X			Pressure returned
AZ	R*4			X		Reported pressure altitude

SUBROUTINE PARA Argument list: None

Description: Initializes the analysis routines; called by ALTER2.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description

None

Common areas	Length	Description
CNTRL	D50	Model parameters
ALPUT	C	ATLER2 parameters
SATRET	2C	Satellite retrieval datasets
INDEX2	64	Report-type flags
PHYSIC	24	Physical constants
ADPTYP	10	Analysis parameters
SMOOTS	18	Surface smoothing flags
SMOOTU	2D0	Upper-air smoothing flags
PRMAND	90	Pressure level constants
PRMANU	90	Reversed pressure level constants
PRMANM	90	Mid-pressure level constants
ADPSC	8	Surface data cutoffs
ADPUC	5DC0	Upper-air data cutoffs
SCM1	18	SCM parameters
GEOS1	318	Geostrophic adjustment parameters
FACOMM	170	Work area
ADPQWT	5DC4	FGGE data quality weights
INDEX1	320	Report-type descriptions
PRINT1	54	Grid points printed out

External references	Description
DINDEX	Report type description identifier

Input/Output ddname	I	O	Method	Description
5	X		NL seq.	ALPUTZ namelist
26	X		U seq.	RMS output
23		X	SSS DA	Temporary direct access dataset

SUBROUTINE PCAL Argument list: P, PBAR

Description: Computes mid σ-level pressures from σ-edge pressures.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
P	R*4	10		X		σ-level edge pressure
PBAR	R*4	9	X			Mid σ-level pressure

SUBROUTINE POTEMP Argument list: P, TBAR, TS

Description: Computes potential temperature at mid-mandatory levels.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
P	R*4	12		X		Mandatory level pressure
TBAR	R*4	11		X		Mid-mandatory temperature
TS	R*4	11	X			Potential temperature

SUBROUTINE PRESIG Argument list: P

Description: Determines mandatory level number from pressure; called by ADPINS.

Restrictions: Mandatory levels are numbered from top to bottom.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
PRESIG	R*4		X			Mandatory level pressure
P	R*4			X		Pressure

SUBROUTINE PSIGMA   Argument list: P2, PO, P

Description: Computes the mid-level pressure of the σ layers from the surface pressure and the top pressure.

Restrictions: P(10) is returned as surface pressure.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
P2	R*4					Surface pressure
PO	R*4					Top pressure
P	R*4	10				σ pressure

SUBROUTINE PSURFE Argument list: None

Description: Computes surface pressure from sea level pressure, sea level temperature, and surface height assuming a standard lapse rate; called by ZTOSIG.

Restrictions: None

Arguments and Arrays Passed	Type	Dimensions	S	F	A	Description

None

Common Areas	Length	Description
CNTRL	150	Model parameters
MODEL	9840	Model arrays
PHYSIC	20	Physical constants

SUBROUTINE PTOSIG   Argument list: None

Description: Interpolates ΔT, ΔRH, Δu, and Δv to the σ levels and adds them to first guess fields; called by ALTER2.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description

None

Common areas	Length	Description
CNTRL	82350	Model parameters
MODEL	7E240	Model arrays (P and σ)
QTYPE	4	Data flag from ALTER2
PRMANU	30	Mandatory level constants
FGQWT	33C4	Dummy array

External references	Description
PCAL	Computes mid-level σ pressure
GTTOT	Computes mid-mandatory ΔT
HUMID	Interpolates relative humidity to σ levels
WIND2	Interpolates wind to σ levels
FILLIN	Computes σ-edge pressure
GEOTOT	Interpolates ΔT to σ levels
FVARIO	Reads 4° x 5° data records
PSURFE	Computes surface pressure from sea level pressure
SPEHUM	Converts relative humidity to specific humidity
GEOTOT	Interpolates ΔT to σ levels

SUBROUTINE PUTWS Argument list: NQ

Description. Dynamic initialization restoring cycle, called by ALTER2.
This routine makes successive calls to the model hydrodynamics with alternately forward and backward time steps in order to balance the mass and wind fields.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
NQ	I*4			X		ALTER2 data flag

Common areas	Length	Description
FOURTH/SMITH/SMOTH/RMWRT/SDOTB/WORK/WORK2/SMOO/TPG/MLFS/CNTRL		4th order model
DBUG	4	Debug flag
MODEL	57540	Model analysis arrays
CYCLE	C	Restoring cycle flags

External references	Description
COMPO	Model hydrodynamics
TWRITE	Output to LOG8 tape

SUBROUTINE QE Argument list: Z1, Z2, NB

Description: Comparison of two character strings of a given length. If the two strings are identical, QE returns .TRUE., otherwise QE returns .FALSE.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
QE	L*4		X			Logical comparison
Z1	L*1	NB		X		Character string 1
Z2	L*1	NB		X		Character string 2
NB	I*4			X		Length of character strings

SUBROUTINE READIN   Argument list. NT2, TAUI, N

Description. Reads in mandatory-level initial conditions for analysis, called by ALTER2.

Restrictions: The dataset must be in the standard mandatory-level format.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
NT2	I*4			X		DSRN for initial conditions
TAUI	R*4					(not used)
N	I*4			X		Data flag from ALTER2.

Common areas	Length	Description
CNTRL	D60	Model parameters
MODEL	7E240	Model arrays

External references	Description
None	

Input/Output ddname	I	O	Method	Description
NT2	X		U seq.	Mandatory-level initial conditions

SUBROUTINE RELDEW   Argument list: P, T, DPD

Description: Computes relative humidity from pressure, temperature, and dew point depression; called by ADPINS. Relative humidity is returned as a value between 0.0 and 1.0.

Restrictions: RELDEW is filled with 99999. if invalid arguments are passed.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
RELDEW	R*4		X			Relative humidity returned
P	R*4			X	X	Pressure
T	R*4			X	X	Temperature
DPD	R*4			X		Dew point depression

Common areas	Length	Description
None		

External References	Description
SATURN	Saturation specific humidity

SUBROUTINE RELHUM Argument list: H, T, P, L

Description: Converts a specific humidity profile to relative humidity.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
H	R*4	L	X	X		Humidity profile
T	R*4	L		X	X	Temperature profile
P	R*4	L		X	X	Pressure profile
L	R*4	L		X		Number of levels

Common areas	Length	Description
None		

External references	Description
SATURN	Saturation specific humidity

SUBROUTINE RINDX1 Argument list: NQ

Description: Fills analysis arrays with model arrays, reversing the grid indices.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
NQ	I*4			X		Quantity flag from ALTER2.

Common areas	Length	Description
CNTRL	83D30	Model arrays
MODEL	57550	Analysis arrays

SUBROUTINE RINDX2 Argument list. NQ

Description Fills model arrays with analysis arrays reversing the grid indices.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
NQ	I*4			X		Quality flag from ALTER2

Common areas	Length	Description
CNTRL	83D30	Model arrays
WORK2	81600	Scaled model arrays
MODEL	57540	Analysis arrays
CYCLE	C	Restoring parameters

SUBROUTINE SAT3ND

Argument list KU, LU, TAU, STNID, DSI, KINS, ZLAT, ZLON KTSN, ELEV, PSF, TSF, DPDSF, PSL, ZNTH ICC, MR PTP, TTP, TLM, WLP, KTW ZM, TM, DPDM, *

Description Reads satellite sounding reports called by ADPINS.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
KU	I*4			X		Format ID = 1,2, or 3
LU	I*4			X		Logical unit number
TAU	R*4		X			Hour of retrieval
STNID	R*4	2	X			Station ID = blank if missing
DSI	I*4		X			Data Source Index
KINS	I*4		X			Instrument type
ZLAT	R*4		X			Retrieval latitude (-90° to 90°)
ZLON	R*4		X			Retrieval longitude (0° - 360°W)
KTSN	I*4		X			Quality mark
ELEV	R*4		X			Station elevation
PSF	R*4		X			Surface pressure
TSF	R*4		X			Surface temperature
DPDSF	R*4		X			Surface dew point depression
PSL	R*4		X			Sea level pressure
ZNTH	R*4		X			Zenith angle
ICC	I*4		X			Channel code
MR	I*4		X			Retrieval code
PTP	R*4		X			Tropopause pressure
TTP	R*4		X			Tropopause temperature
TLM	R*4	15	X			Mean layer temperature
WLP	R*4	3	X			Precipitable water
KTW	I*4	18	X			Temperature and precipitable water quality marks
ZM	R*4	15	X			Mandatory level heights
TM	R*4	15	X			Mandatory level temperature
DPDM	R*4	6	X			Mandatory level dew point depressions

Common areas	Length	Description
None		

External references	Description
VREDE	Variable reading utilty

SUBROUTINE SATSND (Continued)

Input/Output ddname	I	O	Method	Description
LU	X		U Seq.	TIROS-N database

SUBROUTINE SATURN Argument list. T, P

Description Computes saturation specific humidity q_s in g/g from temperature and pressure.

Restrictions. Erroneous values may cause program checks.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
SATURN	R*4		X			Saturation specific humidity
T	R*4			X		Temperature
P	R*4			X		Pressure

SUBROUTINE SBLIZE Argument list. TS, P

Description Stabilizes the potential temperature profile at the mandatory levels.

Restrictions: Profile should be ordered from bottom to top.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
TS	R*4	11	X	X		Potential temperature
P	R*4	12		X		Pressure profile

Common areas	Length	Description
COUNT	8	Unstable profile counters

External references	Description
CONSTT	Stabilizes unstable profile

SUBROUTINE SCALE Argument list: MAP, IR, JR, NX

Description: Plots the alphabetic character or digit depending on the frequency of the quantity and the choice of the maximum number of levels; called by LOC.

Restrictions: None

Argument and arrays passed	Type	Dimensions	S	F	A	Description
MAP	I*4	(46,72)				
IR	I*4					Latitude index
JR	I*4					Longitude index
NX	I*4					Meteorological quantity to be printed

SUBROUTINE SHAPFL Argument list F, NSM, TWIND

Description Shapiro filter applied to a horizontal field called by SMOOTH. No smoothing is done on the pole points.

Restrictions. Set TWIND to .TRUE. if smoothing the wind field.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
F	R*4	(46,72)	X	X		Array for smoothing
NSM	I*4			X		0.5 of the filter order
TWIND	L*4			X		Wind flag

SUBROUTINE SHUM   Argument list. QIN, JNP, IM, GAMMA

Description. Shuman filter applied to a horizontal field called by SMOOC. Filtering is only done in the east-west direction.

Restrictions None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
QIN	R*4	(46,72)				Array to be filtered
JNP	I*4					Latitudinal dimension
IM	I*4					Longitudinal dimension
GAMMA	C*8	3				Filter parameters

SUBROUTINE SIGTOP Argument list: A, B

Description: Interpolates σ-level quantities to the mandatory p levels; called by INCMN.

Restrictions: Only those quantities designated by the NQ flag from ALTER2 are interpolated.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
A	R*4	39		X	X	σ-level profile
B	R*4	62	X		X	p-level profile

Common areas	Length	Description
COUNT	4	Unstable profile count
TYPE	4	(not used)
QTYPE	4	Data flag from ALTER2
PHYSIC	18	Physical constants
PRMANU	30	Pressure level constants

External References	Description
FIND	Vertical interpolation (linear in log P)
PCAL	Computes σ-level pressure
FILLIN	Computes σ-edge pressure
FINDHM	Interpolates humidity profile
HITEMP	Computes pressure level geopotential height
POTEMP	Computes potential temperature
RELHUM	Converts specific to relative humidity
SBLIZE	Stabilizes potential temperature profile

SUBROUTINE SMOOC Argument list: FIN

Description: Shuman filter applied to a horizontal field; called by SMOOTH.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
FIN	R*4	(46,72)	X	X	X	Field to be filter

Common areas	Length	Description
CNTRL	D50	Model parameters

External references	Description
SHUM	Shuman filter

SUBROUTINE SMOOTH Argument list. F, KS, TWIND

Description. Smoother for model fields after analysis called by INSEAL, INSURF and INUPAR.

Smoothing flag KS should be 0 for no smoothing, 1 for Shuman 1-dimensional filter, 4 for 4-point shapiro filter, 8 for 8-point Shapiro filter, or 9 for 9-point smooth-desmooth.

Restrictions: Set TWIND to .TRUE. for smoothing the wind field.

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
F	R*4	(46,72)	X	X	X	Field to be smoothed
KS	I*4			X		Smoothing flag
TWIND	L*4			X	X	Wind flag

Common areas	Length	Description
None		

External references	Description
SMOOC	Shuman filter
SHAPFL	Shapiro filter
$SSMOO9	Smooth-desmooth

SUBROUTINE SMPSL2 Argument list. P, NSM

Description. Two-dimensional Shapiro filter not called

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
P	R*4	(46,72)	X	X		Field to be filtered
NSM	I*4			X		Filter order

Common Areas	Length	Description
CNTRL	D50	Model parameters

SUBROUTINE SM2D   Argument list: A, ISM

Description: Five-point smoother not called.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
A	R*4	(46,72)	X	X		Array to be smoothed
ISM	I*4			X		Number of applications

Common areas	Length	Description
FACOMM	3300	Work area
CNTRL	D50	Model parameters

SUBROUTINE SPEHUM Argument list H, T, P, L

Description. Converts a relative humidity profile to a specific humidity profile, called by PTOSIG

Restrictions. None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
H	R*4	L	X	X		Humidity profile
T	R*4	L		X	X	Temperature profile
P	R*4	L		X	X	Pressure profile
L	I*4			X		Number of levels

Common areas	Length	Description
None		

External references	Description
SATURN	Saturation specific humidity

SUBROUTINE SSCAN Argument list: JM, IM, RSCAN, CD, KNT

Description: Station counting scanner; called by INSEAL, INSURF, and INUPAR. This routine accumulates the number of observations within a given radius about each grid point.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
JM	I*4			X		Latitudinal dimension
IM	I*4			X		Longitudinal dimension
RSCAN	R*4			X		Radius of scan in km
CD	R*4	2		X		Earth coordinates of observations
KNT	I*4	(JM,IM)	X	X		Accumulator array

Common areas	Length	Description
None		

External references	Description
NEXT	Grid point scanner
GRIDCD	Converts grid points to earth coordinates
GCDIST	Great circle distance calculation

SUBROUTINE TAP24 Argument list: NT1, NT2

Description: Creates LOG24 Tape; called by ALTER2.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
NT1	I*4					Input disk logical unit number (23)
NT2	I*4					Output tape logical unit number (24)

Common	Length	Description
CNTRL	4DC	Model parameters
MODEL	F2940	Model arrays
ALPUT	8	Flag for LOG 24 tape

External references	Description
FVARIO	Provides D/A I/O
GETEMP	Computes mandatory level temperature
NEWTPE	New output tape on unit 24

SUBROUTINE TERP Argument list. JM, IM CD, F, FINT

Description. Performs a horizontal bilinear interpolation.

Restrictions. None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
JM	I*4			X		Latitudinal dimension
IM	I*4			X		Longitudinal dimension
CD	R*4	2		X	X	Earth coordinates
F	R*4	(JM IM)		X		Grided field
FINT	R*4		X			Interpolated value

Common areas	Length	Description
None		

External references	Description
CDGRID	Converts earth coordinates to grid coordinates

SUBROUTINE TSFACT Argument list: P

Description: Interpolates σ-level temperatures to the surface.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
TSFACT	R*4		X			Lapse rate returned
P	R*4	10		X		σ-level pressure

Common areas	Length	Description
PHYSIC	70	Physical constants

SUBROUTINE VREDE Argument list. LU, BUF, NWRD, IRET

Description. This routine is used to read records of unknown length; called by SATSND.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
LU	I*4					Logical unit number
BUF	R*4					Input buffer array
NWRD	I*4					Number of full 4-byte words
IRET	I*4					Return code

SUBROUTINE WINDPR Argument list: NS

Description: Upper-air wind check; called by ADPINS. This routine checks both components of the wind observations prior to the analysis. Erroneous winds are filled with 99999.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
NS	I*4			X		Number of reports

Common areas	Length	Description
(Same as INUPAR)		

External references	Description
LEQ1	Single logical comparison
CHKADP	Lateral check
CUTADP	Difference between observation and first guess check
DIFFRS	Difference between observation and first guess

SUBROUTINE WIND2 Argument list: PR, PTOP, T, TT

Description: Performs a linear in log p interpolation of a mandatory-level wind profile to the σ levels.

Restrictions: None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
PR	R*4			X		Reference pressure
PTOP	R*4			X		Top pressure
T	R*4	12		X		Mandatory-level wind
TT	R*4	9	X			σ-level wind

Common areas	Length	Description
None		

External references	Description
FILLIN	Computes σ-edge pressures

SUBROUTINE $SMOOD   Argument list   QIN

Description   Nine-point smooth-desmooth on a global two-dimensional field, called by SMOOTH.

Restrictions   None

Arguments and arrays passed	Type	Dimensions	S	F	A	Description
QIN	R*4	(46,72)	X	X		Global model field

Common areas	Length	Description
FACOMM	107800	Work space
CNTRL	150	Forecast parameters

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